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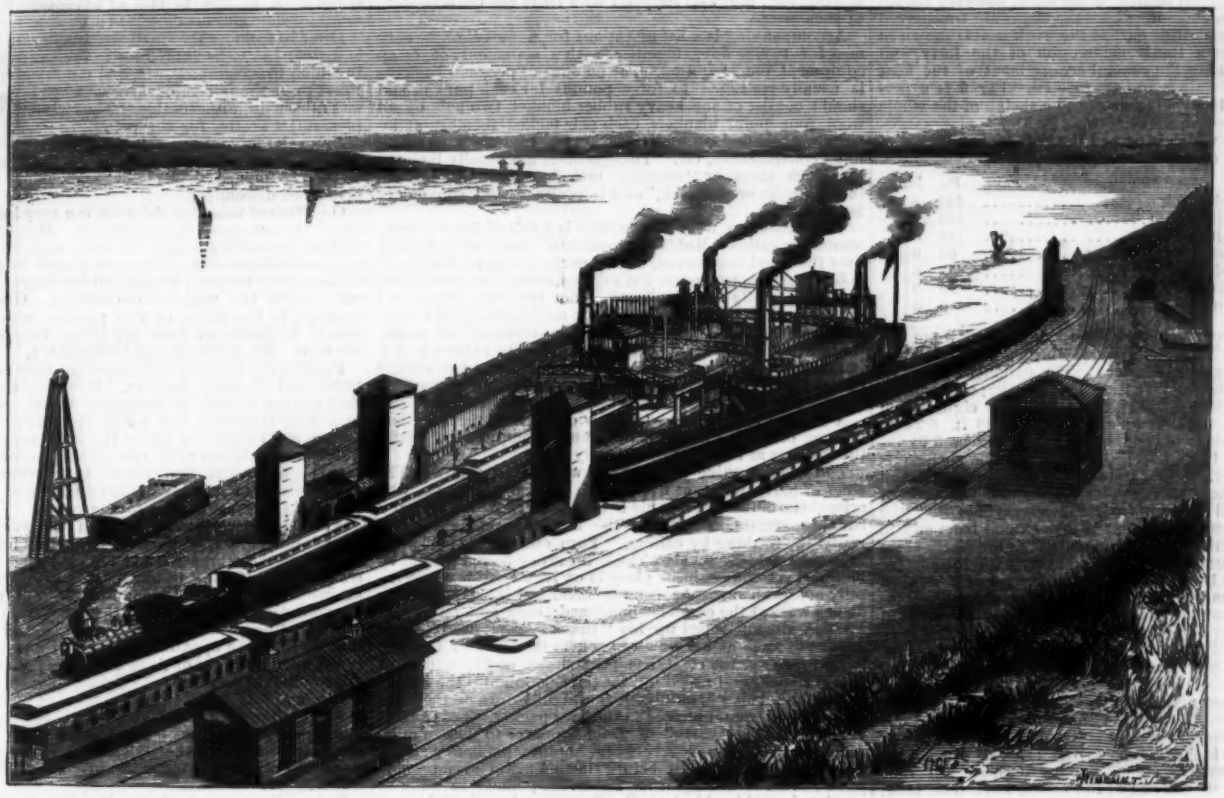
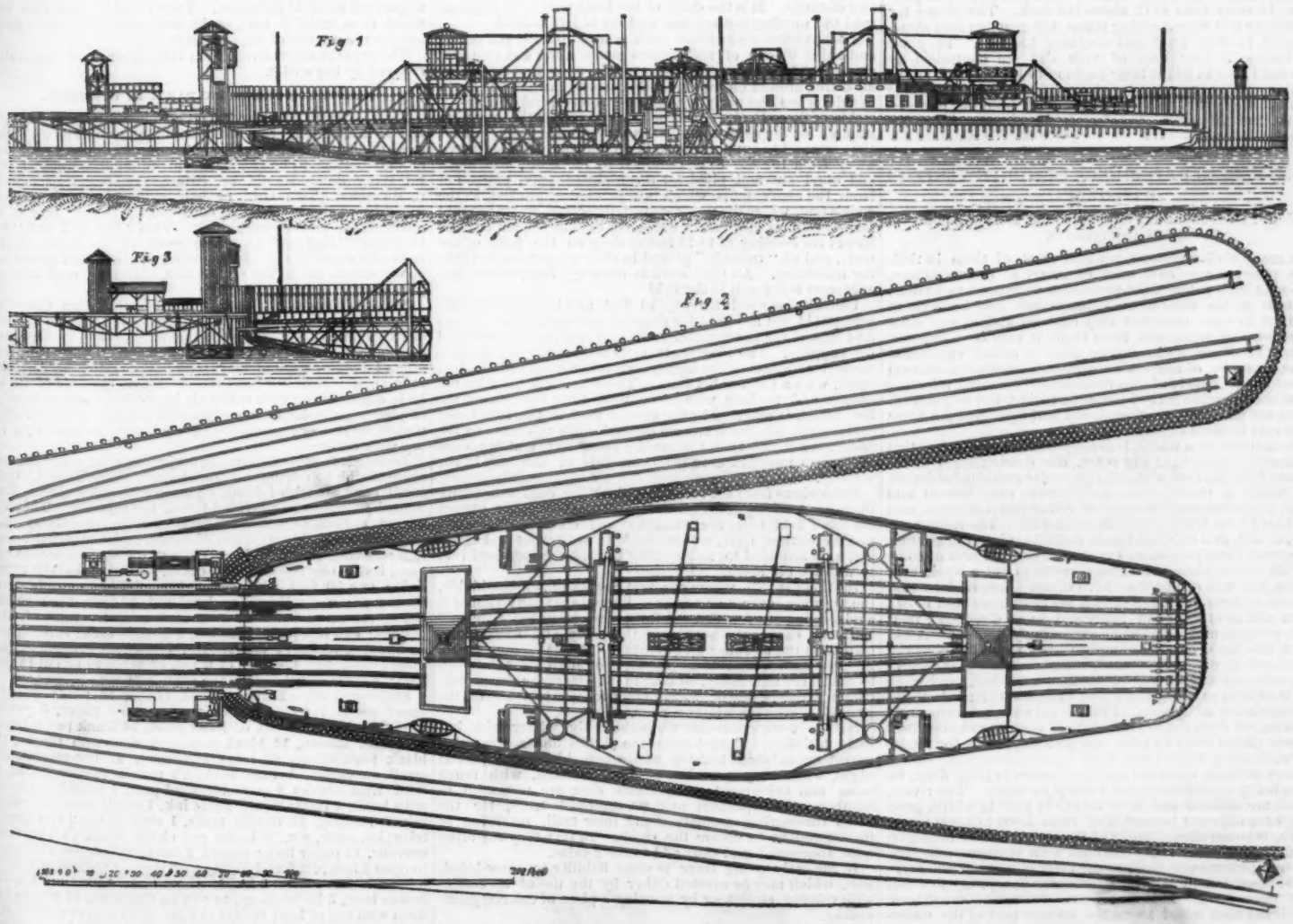




THE CENTRAL PACIFIC RAILWAY FERRYBOAT, SOLANO. (See next page.)

THE CENTRAL PACIFIC RAILROAD FERRY.

Trains running to and from Oakland upon the Central Pacific Railroad were formerly compelled to make a somewhat wide detour to skirt the eastern and southern sides of Pablo Bay, which is one of the indentations of San Francisco Bay. Oakland is situated immediately opposite the city of San Francisco, that stands on the north point of the narrow strip of land forming the western inclosure of the bay; the distance between Oakland and San Francisco is about five miles. Some thirty-five miles to the west, and a little to the north, Pablo Bay contracts until the distance between its north and south banks is only about two miles; this contraction forms the Straits of Carquinez, and on each side, opposite each other, are the towns of Benicia and Port Costa. It is at this point that the Central Pacific Railroad Company have established the ferry which forms the subject of the illustrations. By means of it the circuitous route around Pablo Bay is avoided, and passengers are taken direct to Benicia and then to Oakland, the terminus of the railway. Fig. 1 is a longitudinal section of the ferry, showing the arrangement of the stage by which the trains are transferred to and from the boat; this part of the work is also shown in Fig. 2. Fig. 3 is a transverse section of the ferry, and Fig. 4 a plan showing the general arrangement of the boat as well as of the sidings and approaches. Fig. 5 is a perspective view of the boat, and Fig. 6 a sketch of the whole work.

The ferry boat, which is named the Solano, is a vessel of 3,540 tons, and is of the following dimensions:

	Ft.	In.
Length of main deck	404	8
" hull	406	2
Width over all	116	0
" between wheel casings	64	9
Height amidships	18	6
" at ends	15	9
Draught when loaded	6	6

The boat is propelled by two separate vertical beam engines; they were built by Messrs. Harlan and Hollingsworth, of Wilmington, Delaware. The cylinders are 5 ft. 2·24 in. in diameter, and 11 ft. 0·28 in. stroke; each engine is intended to develop 2,000 H. P. There are eight steam boilers, each 7 ft. 0·25 in. in diameter, and 28 ft. 0·24 in. long. They are made of steel, and have 143 tubes 3·94 in. in diameter, and 16 ft. long; the total heating surface is 19,630 square feet. The wheels are 30 ft. in diameter, and have 24 floats; each wheel can be worked independently of the other. It will be seen from the engravings that the ferry has four lines of rails, and as they extend from end to end, there is sufficient accommodation for forty-eight freight cars or twenty-four passenger cars, with locomotive and tender. The boat is chiefly used for passenger service, freight being taken by the old route, and transferred at Oakland to finish running to San Francisco. As the amount of freight thus carried is very considerable, the service is an important one, and the boats are large enough each to carry a number of wagons, which are unloaded in the San Francisco depot.

The general construction of the Solano is indicated in the illustrations. Beneath each line of rails runs a deep Pratt truss, the top flange of which is attached to the deck, and the bottom to the hull of the boat; the latter is divided by bulkheads into twelve compartments. There are four balanced rudders at each end of the vessel, 10 ft. 6 in. long, and 6 ft. 6 in. high; these are worked by hydraulic steering gear, but can be actuated by hand when desired. The pilot house is more than 40 ft. above the deck. The stages for embarking and disembarking trains are massive iron structures, 98 ft. 6 in. long, and weighing 150 tons. They are provided with four lines of rails, and are controlled by hydraulic gear to adapt their position to the rise and fall of the tide. We have reproduced the illustrations and some of the particulars of this interesting work from our contemporary, the *Nouvelles Annales de la Construction.—Engineering.*

ENGINEERING EXPERIENCE IN NORTHWESTERN WISCONSIN.

By F. W. D. Holbrook, Member of the Boston Society of Civil Engineers.

As many civil engineers, perhaps most of them in their early practice, are, as it were, creatures of circumstances, following such paths of the profession as happen to be open to them at the close of each engagement, not knowing at any time in what direction they may be called, nor what duties may be incumbent upon them, it may be of interest to some to obtain an idea other than by actual experience of the character of the work involved in making a railroad survey in the woods of Northwestern Wisconsin, referring not to the scientific part of the undertaking, but to practical points not generally mentioned, but still equally if not more important to those engaged in it.

The country, as a whole, is densely wooded, so much so that in summer, standing at any point, the configuration of the ground fifty (50) feet distant is generally undistinguishable. The timber is mostly white and Norway pine, balsam and birch, with occasional swamps of cedar and tamarack, and some hardwood timber is at times met with. The trees, however, do not, as a rule, send their roots deep into the ground, but spread them just below the surface over an area of some ten (10) feet in diameter. This gives them but a weak hold on the soil, and windstorms have at times occurred so that for two or three miles at a stretch the trees have been blown down and lie crossed and interlaced in all directions, their roots upright, making passage exceedingly difficult. Areas where this has occurred are known as "windfall" districts.

The soil is red clay or marl, which when wet is exceedingly slippery and sticks "closer than a brother," and when dry is so hard as to require a pick to excavate it; it is therefore expensive to handle. In railroad cuts it is constantly breaking off from the top and sliding, and has to be confined in such places often by piles and planking, stone for retaining walls being seldom met with.

Many streams cross the country, generally lying deep, ravines being sometimes found 100 feet in depth. The rivers, which are shallow and from 50 to 150 feet in width, generally have adjacent bottom lands from 1,000 to 2,000 feet in width, between abrupt banks of from 30 to 50 feet in height; some of these have rocky bottoms with frequent falls, giving very picturesque views to the lover of natural scenery.

The snow fall in winter is generally heavy, say five feet deep on a level. This necessitates the use of snowshoes, but, being thus raised above the greater part of the underbrush, together with the absence of foliage, renders the view of the country clearer to the explorer, and as in the absence of roads and bridges supplies can more easily be transported at this season, the winter is usually chosen for the purpose of surveys.

The organization of a party for a railroad survey consists of the chief of party, transitman, leveler, rodman, flagman, two chainmen, four axmen, cook, eight packers, and sometimes a topographer, about twenty in all. All equipment and supplies are transported on the backs of packers by means of a leather pack-strap for each man, which is attached to the load, and of which the broad band is worn against the forehead. These packers are usually Indians (Chippewas) or half-breeds, a white packer being rare in this vicinity. It is impracticable, in the absence of roads, to make use of any ordinary method of transportation, and on this account the outfit carried should be quite limited, and consist only of necessaries. It should be put up in compact form, and the shape and weight of the separate parcels be adapted to the mode of carriage. On this account camp stoves and kettles are made oval, the latter in nests, while these, as well as folding boards for draughting, bread-mixing, etc., are well supplied with rings for the attaching of pack-straps.

Accompanying is a list of rations for a party of twenty men for twelve days, together with a statement of camp equipment, etc., required. The amount of personal baggage is usually restricted to forty pounds for each person, and should consist of one heavy rubber blanket, two pair of all wool, four point blankets, each pair tacked together at intervals, a change of underwear, extra trousers and socks, toilet conveniences, etc. These articles are usually inclosed in a duck sheet, or "seamless sack," and strongly corded into a bundle or "tussock," as it is locally termed, convenient for packing.

The customary wear for the body is a suit of brown duck, sometimes called "Montana broadcloth," lined with flannel, over the usual underwear. Some perfer a suit of Mackinaw goods, but the latter are not as impervious to water, and are more easily torn by brush. For the feet, two pair of woolen socks, over which are either moccasins or oil tanned boot packs. Felt boots, with rubber overshoes, are sometimes worn. As wet feet, however, are to be expected, it is important to wear something that can be easily put on and off, and for this purpose the ordinary leather boot is entirely unsuited.

A fur cap for the head to draw down over the ears, and mittens or warm gloves for the hands, complete the outfit, the weather at times being intensely cold.

The usual routine of the day's work is as follows: The chief of party wakes at five o'clock and calls the cook, who arises, starts the fire, fills his kettles with snow if not near a running stream, and rouses the men as soon as water is ready for washing by calling, "Turn out, turn out!" at or near their tents. By six o'clock breakfast is ready, and by half-past six the engineer party is on its way to work, generally not far away. As soon as breakfast is over and the dishes washed the camp is abandoned; each man on getting up has already roped up his "tussock," the head packer assigns to each of his crew of packers the share of the load he is to carry, the cook has packed *his* outfit, and tents being struck and rolled up, the packers take up the line of march, this being determined the night before by the chief of party and communicated to the head packer. The packers usually make a "carry" of from a quarter to half a mile, dump their loads and return for another pack, and so on, bringing everything up before starting again ahead. The pack carried is usually from 100 to 200 pounds in weight, regulated considerably by bulk. Some men have been known to stand up under 700 pounds, but not be able to carry it any distance. It is the duty of the head packer to superintend the moving and see that nothing is left behind.

About eleven o'clock the cook comes up with the party, and aided by one of the packers starts a fire and prepares dinner. This is served in the open air, spread on the snow, all sitting around on logs or fallen trees. An hour is given to this, when the party resume their interrupted duties.

About three P. M., the head packer selects the camping ground for the next night, poles and crotches are cut for the tents and to support the cook's pot-hooks, snow is cleared away from the site to be occupied by the tents, fires made and wood cut and piled for the night's supply, paths cut from the men's tents, which are previously pitched, to the cook's tent, where the meals are usually served, water brought for the cook or clean snow procured, balsam boughs cut and spread for bedding 12 to 15 inches deep on the floor of the tents, and all "tussocks" placed in their proper places ready for unfolding. All this work is done by the packers, the engineers being still in the field.

Usually three wall tents 8×10 feet and two shed or half-tents 8×14 feet are used for sleeping quarters. Two of the first named for the engineer staff, and one for the cook and his supplies. The shed tents are open on one side and are pitched with these sides facing each other, about fifteen feet apart, with a log fire between. These are occupied by the axmen and packers, who sleep with their feet toward the fire, which is reflected by the canvas roof to the interior of each tent. All tents are so pitched with reference to the prevailing wind that the smoke from any tent-fire does not cause annoyance to the occupants of the tents in the vicinity.

Somewhere from six to seven o'clock the engineers return to camp, finding supper all ready for them. After supper the day's field notes are examined and checked, plans and profiles worked over, repairs made to snowshoes and clothing, axes attended to, and by nine o'clock the men begin to turn in for the night.

In these woods, where constant chopping is unavoidable, the progress, even on a compass line where heavy timber is avoided, is not over three miles a day, often but two, and thus the camp can keep near the party and avoid long tramps in the morning and evening. Besides chopping in line, the axmen also blaze the trees on both sides, in order to retrail the line easily, so that in summer one frequently comes across a line of blazes eight to ten feet above the ground, marking a winter survey.

So the work continues throughout the winter with but little variation. Occasionally the parties find a porcupine curled up in some tree-top and secure him for a feast at night, when they partake of him, cooked, with much noise and enjoyment. Sometimes deer are met with in numbers. The packers also set dead-fall traps, for the small fur-bearing animals along their trail, returning to them Sundays to secure the result. In this they are often quite successful, and thus add to their gains.

In the early spring there is some liability to snow-blindness, which may be averted either by the use of spectacles with colored glasses or by wearing a piece of colored gauze veiling.

When the snow melts away comes a month or two of extreme wet, the ground appears swampy in every direction, even on summits and where the natural slopes are steep. One wades in water to the knees, and climbing over windfalls, jumping up and down and from tree to tree as they lie on the ground, balancing one's self along their slippery trunks, tripping, falling, makes progress slow and tedious.

The snow gone, the reign of insects commences, mosquitoes, gnats, midges, horseflies, deer-flies, "no-see-ums," which are almost imperceptible to the eye but torments to the feeling, and more flies of various names swarm in myriads, and render it doubtful whether one should be thankful for existence. Various compounds of oil of tar, pennyroyal, camphor, and, glycerine are now brought forth and spread over the face, neck, and hands, or gloves and bavelocks are worn to protect one from these pests. Coverings, however, are suffocating, and the influence of the tar, etc., is of but short duration, requiring frequent and renewed daubing, so that, after all, to "grin and bear it" seems to be the best resource. At night sleep can be secured by means of canopies, the top of unbleached cotton, the sides of cheese cloth, so attached to the tent as to inclose each sleeper. A canopy is also of advantage in inclosing the draughtsman and his table when he is at work.

Later in summer the small streams dry up entirely; water is scarce; has to be hunted for in the swamps; holes are dug in which to accommodate it, and much suffering arises from thirst until the fall rains arrive, when it is again swampy and otherwise disagreeable. The winter, after all, is the pleasantest season for surveying.

From the foregoing a fair idea can be obtained of what may be in store for some of you in the future, but "forewarned is forearmed," and the knowledge here given may save from discomfort.

On a trip of this kind the cook is a very important personage to the success of the expedition. Men to work well and without grumbling require to have their food cooked well and promptly served. The cook should be proficient in his calling, good natured, prompt and willing. Cooks are, as a rule, cranky and addicted to drinking. Great care should be taken in the filling of this position, and whoever fills it should be protected from any abuse, verbal or other, from the men. His rights should be respected.

Packers are a source of annoyance; they are averse to dictation and all hang together. Knowing their importance, they are apt to take advantage of it, and are liable to leave in a body if care is not taken in handling them. Their management should be left to the head packer, who should himself be selected with care on this account, and who in turn should select his crew so as to secure harmony and proper discipline. They are unreliable, and generally go on a spree as soon as they get to a town.

Accidents occasionally occur in the woods from falling trees. Sometimes, while they are being felled, they jump back from the stump against the chopper; sometimes they set other trees falling in unexpected directions by dropping against them, and a looker on must keep his attention awake to avoid danger. A storm or the concussion of trees falling will sometimes cause the dropping off of tall dead stubs, and thus catch a man apparently far out of danger. In pitching camp, the proximity of these dead trees should be avoided, or they should be felled.

It is not safe for a single member of a party to stray off alone into the woods without a pocket compass, and it is advisable for him to blaze his way as he goes. One's bearings are very easily lost; the constant twisting and turning to avoid or get around obstructions soon mystifies one as to his course.

It is well to "cache" supplies for the party at various points along the proposed line of survey in advance of need, to prevent possible privation. They should be carefully covered in a small A tent, or by tent cloths, and protected against the attacks of wild animals.

The experiences referred to in this sketch have been fully enjoyed by the writer.

OUTFIT FOR SURVEYING PARTY IN WISCONSIN.

Tents.—Three 8 feet by 10 feet of 4 breadths of duck wide and 5 breadths long, these to be wall tents; walls 3 feet high; roofs of 10 ounce duck; walls and ends of 8 ounce duck; flap around bottom to be 13 inches wide of 8 ounce duck; ropes for tying down should be strong, say one quarter inch in diameter. Two shed or half tents 14 feet long, or 6 breadths of duck; to have ends and a "stoop;" roof of 10 ounce duck; ends 8 ounce duck. Two 7 feet by 7 feet "A" tents for "caching" supplies; roofs of 10 ounce duck; ends of 8 ounce duck. Ridge poles, crotches, and pieces for above can be cut in the woods, and, therefore, need not be purchased.

Stoves.—Three oval stoves of No. 20 sheet iron, diameter 12 inches and 18 inches, 2 feet 3 inches high. Door to have clear opening of 8 inches by 10 inches. Draught hole under door and near ground 2 inches diameter. Heavy iron rim around bottom edge of stove; no bottom; four loose rings at top and bottom for pack strap. Stovepipe hole of tin to be in center of top with collar 1¼ inches high; three lengths of pipe to go inside of stove loosely; damper in one length; pipe to be riveted; one stove for cook tent, to have hole in top with cover.

Instruments, etc.—One transit (adjusting pins, screw driver, spare plumb bob strings accompanying). One Y level. One small compass with folding sights and Jacob's staff. Red flannel covers to be provided for all instruments. They do not sweat them as rubber covers do, protect equally against rain, and are visible at quite a distance, all instruments being left standing in the field at close of the day's work. One hand level; one 100 foot steel chain, brazed links, six extra links; one 50 foot steel chain, brazed links; one 50 foot linen tape; one self-reading level rod, 12 feet; three range poles; six axes, handled, two of 3 pounds, four of 3½ pounds; two hand axes handled, 2 pounds each; three spare ax handles, hickory; one shovel; one small grindstone (12 inches diameter), bearings of wood, crotches to be cut in the field; bundle of cut hide for snowshoe filling.

Stationery, etc.—Eighteen field books, 10 yards Manila paper about 2 feet wide, 20 yards profile paper, 5 yards tracing vellum, 1 block of letter head, 24 blank pay rolls, 2 blocks of memo., 12 blank vouchers, 6 scratch blocks, 12 blank requisitions, 25 large envelopes, 12 inventories, 50 small envelopes, 1 time book, 24 pencils (Faber No. 5), 1 book time checks, 6 penholders, 24 pens, 1 indelible pencil with leads, 1 bottle liquid India ink, 1 small bottle copying ink, 6 rubbers, 12 thumb tacks, 1 steel ruler, 2 feet long, triangles, scale, etc., 2 boxes red chalk, French's Venetian crayons, 12 paper tacks, tinned, 1 drawing board—folding—to open 3 feet × 2 feet 6 inches with rings, 1 stationery box—6 × 10 inches—2 feet 4 inside dimensions, with tin tray, 15 inches long, 3 inches deep, to rest on slides, top of tray to be flush with top of box; covers to have strap hinges and fasten with bent hasp and staple, to have half a dozen loose rings attached for pack strap, 3 tin cases, 2 feet long, 5 inches dia-

meter, cover to shut over 4 inches, with loose rings for pack strap.

Cooking Outfit, etc.—Two dozen each of plates, cups (tin ware), knives and forks, table spoons; one 6 quart pan, two 4 quart pans, two 2 quart pans, two 3 pint pans; two 12 inch frying pans with long handles, two long handled spoons, 1 meat fork, 1 carving knife, 1 butcher knife, one 1 quart tin dipper, 2 canteens with screw top, 1 ladle, 1 skimmer, 1 coffee kettle, 10 inch diameter, 10 inches high, of heavy tin, 1 teakettle, 9 inch diameter 9 inches high, to rest in above; 1 tin baker, 28 inches long, riveted joints, strengthened by angle irons on edges; 1 bread pan of galvanized iron, to fit into baker; 1 dish pan of galvanized, iron to fit

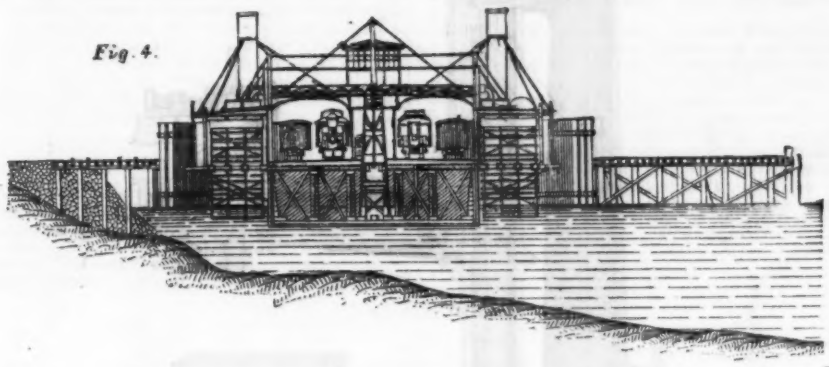


Fig. 4.

CENTRAL PACIFIC RAILWAY FERRYBOAT, SOLANO. (See opp. page.)

into bread pan; 1 nest of oval galvanized iron camp kettles with flat covers to shut over, to nest easily; one 12 inches wide 12 inches high, one 11 inches wide 11 inches high, one 10 inches wide 10 inches high, one 9 inches wide 9 inches high, one 8 inches wide 8 inches high, all with loose wire handles; 6 pot hooks; 1 folding bread board, to open 2 feet by 2 feet 6 inches; 1 rolling pin, 6 yards crash toweling, one 1½ gallon keg, 100 feet half inch Manila rope, 1 mess chest 6 by 10, 2 feet 4 inches inside, divided into pigeon holes, with hinged cover, hasp, and staple; 1 bread box, 1 foot by 1 foot by 2 feet 6 inches, with sliding cover.

Rations.—Supplies for twenty men, twelve days—25 pounds butter, 170 pounds ham, 75 pounds canned corned beef, 50 pounds mess pork, 300 pounds flour, 100 pounds granulated sugar, 50 pounds brown sugar (in part for syrup), 10 pounds tea, 15 pounds coffee, 70 pounds beans, 25 pounds rice, 25 pounds dried or evaporated apples, 25 pounds dried peaches, 50 pounds prunes, 25 pounds raisins, 10 pounds currants, 12 pounds baking powder, 10 pounds salt, half pound ground pepper, half pound ground ginger, 1 pound ground cinnamon, 12 bottles prepared mustard, 6 boxes matches (300 in box), 12 pounds soap, 15 pounds candles. All to be of the best quality, to be put up in 50 pound lots, convenient for packing, double sacked or boxed.

MALLEABLE IRON CASTINGS.

THE term "malleable iron" in this connection is employed to designate those castings which have had their metal than graphitic carbon, which is very hard to burn out. White cast iron, or what is also called forge pig, is to be preferred for making malleable castings, in consequence of the carbon it contains existing in it in the combined state and not the graphitic. In addition to the difficulty there is in burning out graphitic carbon, there is another reason why gray pig should not be used, and that affects the appearance of the castings. Let us suppose an article made of gray pig, rich in graphitic carbon; if, after a protracted heating in contact with oxidizing substances, the graphite (*i. e.*, carbon in the graphitic state) is burned away, the place previously occupied by it in the metal will have become empty; the article will be porous and will show it. An article, however, cast from white pig, will appear with the same sharpness of outline and smoothness of surface after the annealing operation as it did before. White metal is, therefore, preferable to gray for this class of castings, provided it contains sufficient combined carbon to insure the fluidity necessary for sharp castings.

The castings are packed in boxes with suitable ingredients, and are kept in an annealing oven at an equable heat for a time varying according to the form and size of the castings. With respect to the ingredients, hematite ore is generally employed, also the iron scale or block oxide detached from wrought iron in the process of forging or rolling. These ingredients give out, when heated, a considerable amount of oxygen, which, when in contact with the heated castings, removes from them the carbon in the form of carbonic acid gas. The magnetic scales of oxide of iron and the iron ores used should be as free from silica and earths as practicable to prevent their fusing at the temperature of the annealing furnace, and forming a slag or cinder, and so hindering the oxidizing action. The decarbonizing process changes the metal so as to make it malleable; and though it has not the peculiar fiber that rolled or hammered iron possesses, it exhibits many of the properties of wrought iron. Malleable castings may be bent, hammered, and twisted without fracture, and can be exposed to concussion, torsion, and other sudden strains which could not be endured by ordinary cast iron. The thinner the casting the more rapidly it is transformed into malleable metal. Thick castings, if the heat has not been sufficiently high or protracted, will exhibit when fractured a sort of gradation of the transformation from cast to malleable iron. The outer parts, which have been thoroughly decarbonized, are gray, easily filed and drilled, and without brittleness; and proceeding toward the center, the qualities of color, softness, etc., gradually change, until we find the white iron exactly as put into the furnace. These annealed castings are valuable for many situations where forged wrought iron would either be very expensive or altogether impossible to deal with. In a steam engine or other machine there are many small parts which are subjected to such sudden shocks and torsion that cast iron must be of extreme thickness to endure them, while, at the same time, they do not require all the ductility and elasticity of wrought iron. In such cases malleable castings are useful. Again, unlike wrought iron, however complicated their required form, they can be produced at a reasonable cost; and if, owing to a repetition of the same machine, a large number of similar castings have to be made, the economical advantages afforded are obvious. The ring or sound of malleable castings, when struck, very nearly approximates to that of wrought iron. Cross heads, links, eccentric straps, small cranks, locomotive axle boxes, axle box lids, small hydraulic cylinders, are all cases where something tougher than ordinary cast iron is needed, and where the expense of wrought iron may be avoided. Malleable castings may also often be substituted for copper and brass with advantage. There are very few machines in which some malleable castings may not be used with advantage. The cost of malleable iron castings depends largely upon the size and quantity of the articles; and any pattern being given, the cost of malleable castings from it will be from 70 to 80 per cent. more than ordinary castings from the same pattern, which increase is necessitated by more labor, the consumption of fuel in annealing, greater cost of pig, etc. The price is usually from 3d. to 6d. per pound, depending upon quantity from a single pattern, form, weight, etc.

The pig iron used for making malleable castings is, at some works, white charcoal pig. It is melted in cupolas or reverberatory furnaces. A reverberatory furnace consumes more fuel and produces more waste than a cupola, but the metal runs from it is purer, because it is not melted in direct contact with the fuel, and therefore does not absorb its sulphur and other impurities. The furnace also has the advantage that should the pig contain too much carbon, part of it may be removed by the oxidizing action of the flame. The castings are mostly made in green sand, from metallic patterns, which insure smoothness of surface and constancy of shape to the castings. When they are cast, they are comparatively brittle. They are put into a revolving cylinder to deprive them of the adhering sand, and when thus cleansed are packed close in rectangular iron boxes, with alternate layers of powdered iron scales from rolling mills. Not counting the time necessary for raising the temperature and the cooling off, the articles are subjected for about a week to a white heat, not sufficient, however, to melt what still may remain in them of cast iron. Any adherent oxide is removed by placing the castings again in the revolving cylinder, when the process of malleable iron making is finished. The oxygen removed from the oxide of iron (the scales) used in the annealing may be replenished by grinding the scales and then rusting them with (1) a solution of sal ammoniac, or (2) by wetting the powdered scales several times with water only, and stirring and drying them on the top of the annealing furnace.

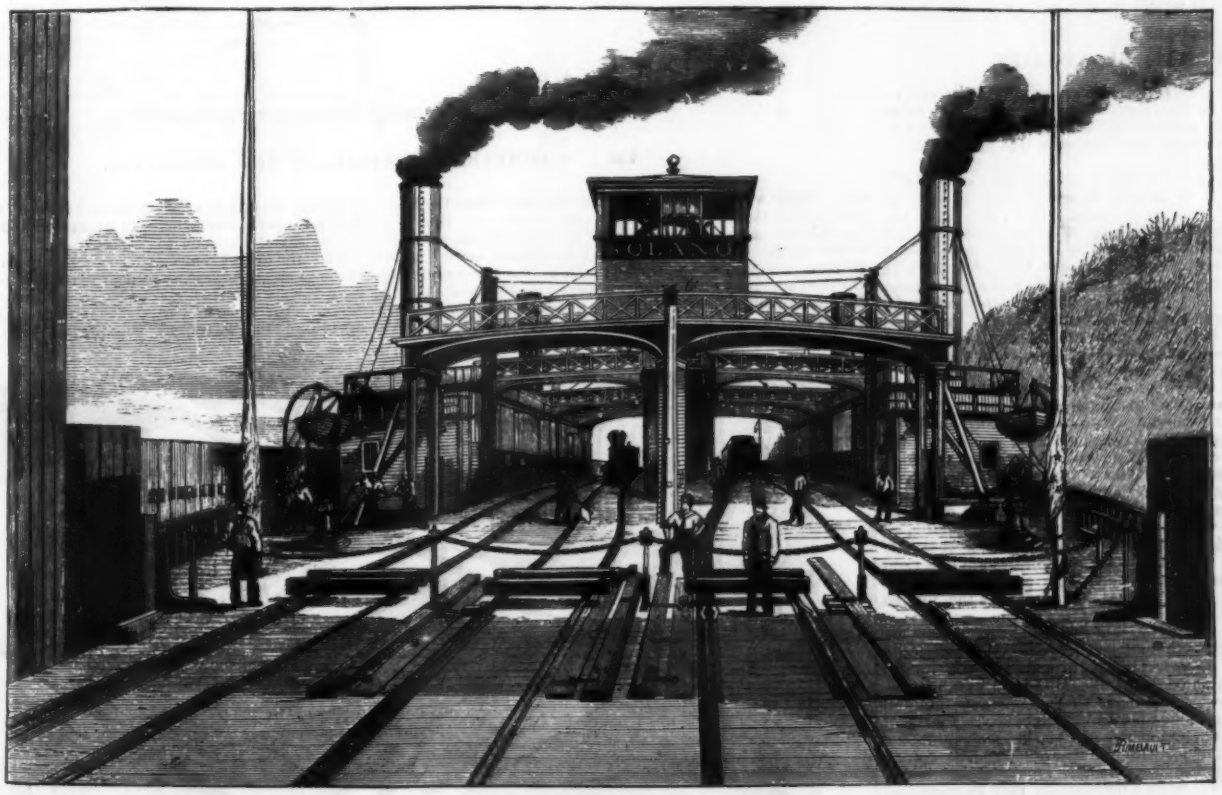
So long ago as 1722, Reaumur published the fact that the heating of cast iron castings embedded in red oxide of iron softened the metal perfectly and much more rapidly than all the other means he had tried for the purpose, such as chalk, calcined bones, etc.

The following are some methods which have a bearing on this subject:

Cast iron castings surrounded with animal ashes and exposed to a fire not sufficient to melt them, become in a shorter or longer time, according to the strength of the fire and thickness of the metal, so soft that they may be drilled, chipped, and filed. Castings may also be softened by placing them in an iron box, surrounding them with sawdust, and closing up the box with clay to exclude the air, and subjecting it to a red heat for several hours. The castings must be cold before they are withdrawn.

Malleable iron, it is said, may be made in the crucible of a brass furnace as follows:

To 10 pounds of the molten metal in the crucible add a mixture consisting of 2 ounces fluoric acid, 1 ounce nitric acid, and 1 ounce saltpeter. When you have cast off the patterns, the castings want keeping at a red heat for three or four days, in iron boxes, in a furnace.—*Mech. World.*

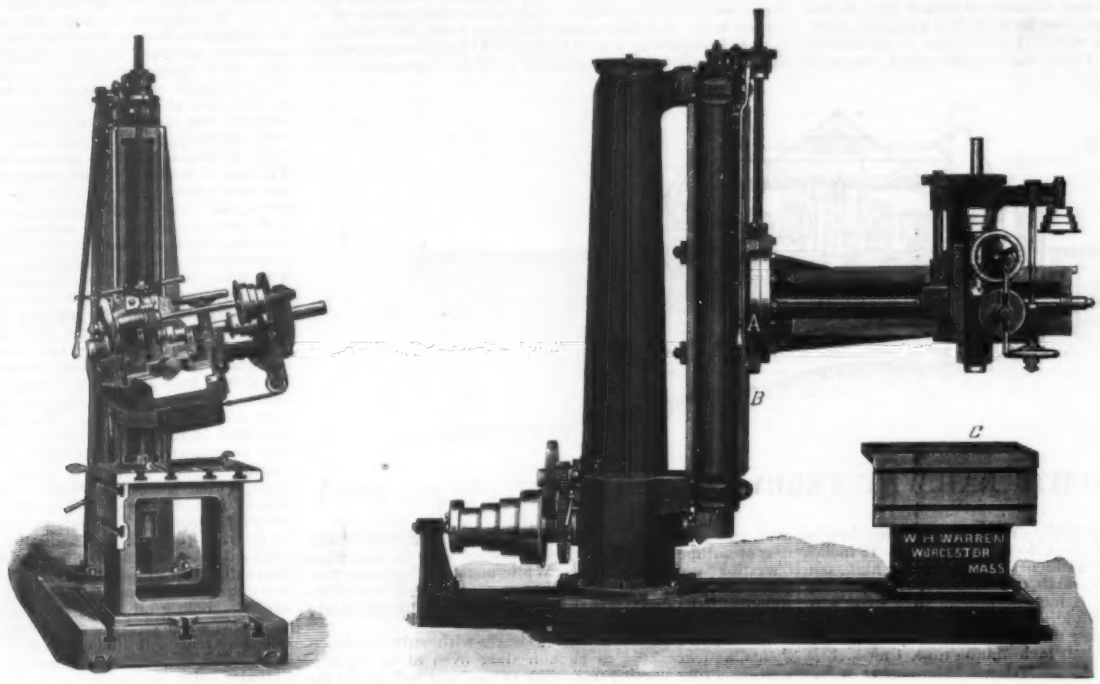


CENTRAL PACIFIC RAILWAY FERRYBOAT, SOLANO. (See opposite page.)

brittleness entirely or partly removed by the operation of annealing. Castings, if subjected to an after process of annealing, may be softened, and will acquire some of the toughness of wrought iron. Annealing consists in burning out the whole or part of the carbon contained in the castings. Cast iron is mainly a compound of iron and carbon, in which the carbon is partly combined with the metal and partly mixed with it, and when carbon exists in cast iron mixed with the iron, the carbon is said to exist in the "graphitic state." Combined carbon is more easily removed from the

WARREN'S RADIAL DRILLING MACHINE.

THE accompanying engraving represents the latest improvements on the radial drill built by W. H. Warren, of Worcester, Mass. The long-desired compact arrangement of a balanced spindle, working from a vertical to a horizontal position without adjustment, is here obtained. The spindle is raised or lowered in an instant by use of lever handle, and driven by worm gear and rack when desired. The head is moved on arm by means of hand wheel, so arranged with gears and rack that the operator can move it quickly, having the advantage of being over his work, instead of using screw at end of arm. The arm can be turned to any degree, as it swivels on graduated shoe, A, which is planed on tracks on vertical bed, B, secured by four bolts. The utility of having the shoe planed on tracks is manifest when the operator desires to throw the arm over and drill and counterbore, and yet retain its exact position with the work. The great distance between bearings on vertical bed, B, obviates the necessity of tightening and loosening the grip bolts on surface drilling, yet retaining a rigid but easy swing to arm. The arm is raised or lowered by power by simply working a lever. Back gears, with large cone of four changes, give sufficient power and variety of speed. The gearing is all cut from solid metal, all shafts are steel, with long and large bearings, all slides are scraped fits. C represents a portable table, which can be readily detached, and large work placed over floor table.



IMPROVED RADIAL DRILLING MACHINE.

MERESSE'S TACHYGRAPH.

THIS instrument, like the pantograph, is designed for copying all kinds of drawings, and either enlarging or reducing them with geometrical accuracy. But it recommends itself by certain essential features that result from its peculiar construction.

As in the pantograph, Mr. Meresse employs, too, a jointed parallelogram, A, B, C, D' (Fig. 2), but one whose two opposite sides, C, D', have a constant length, the other two consisting of rules, A, B, divided off in the same way, and one of them being prolonged to the center of similitude, A P. It may be said that the instrument represents in plan the beam of a steam engine provided with a Watt parallelogram. The beam, A, A', is here carried by rollers which facilitate the moving of the piece over the plane of the figure. The point is fixed in a slide, K, at the extremity of the rule, A, A', so that its position may, at will, be so regulated as to bring it upon the straight line passing through the center of the joints, h, h', of the two connecting bars, C, D'. The entire apparatus is confined within a plane near that of the paper, thus reducing the deviations to which the pencil and style would be exposed in consequence of a warping of the parts. The short rule, B, B', is of wood, as is also the long one, A, A'. The bars, C, D', that connect them are of copper. All the joints, h, h', h'', h''', situated outside of these different parts form the corners of the geometrical parallelogram, e, e', e'', e''', whose play affects the transformation of the figure. In order to place the style and pencil, it is only necessary to make sure that their extremities are in a right line with the center of similitude, P, g, g'. These fall, besides, on the right lines, e, e', that limit laterally the jointed parallelogram.

It may be seen that in such a system as this, where the parallelogram is reduced to its four geometrical angles, a slight alteration of its material sides may always be corrected by a proper regulation of the pieces. Before beginning operations, certain verifications have to be made, and these all consist in ascertaining whether three points are in a straight line, and, if not, in bringing one of the said points upon a right line that coincides with the two others. The coincidence once secured, the instrument is regulated and operations may be begun. Such a preparation may be compared with the tuning of a stringed instrument.

The use of a wooden pantograph of large size is attended with considerable expense, and does not insure of much accuracy, since wood of great length inevitably warps. Such an inconvenience is avoided in the tachygraph through the means provided for regulating it. The apparatus is rendered complete by the following accessories:

1. A style holder and a pencil holder, which move upward and downward in a slot formed in a vertical piece affixed to slides, E and G, on the copper coupling bars, C, D'.

2. Three rollers, which are placed on the longer rule, one of them at about 10 centimeters to the right of the axis, another to the left of the bar, D', and both on the inside, and the third to the left of the bar, C, and external to A. Two other and jointed rollers are adjusted to the short rule, to the left of the copper bars. The one to the extreme left may be replaced by a simple bone or ivory button sliding upon the paper or table. The height of these rollers is so calculated as to raise the entire apparatus one centimeter above the table.

3. A mass of iron, M, whose shank carries the axis of the long rule, which terminates at its lower extremity in a fine point. When the place at which this axis is to be fixed has been determined, a small ring is laid flat upon the table, and above it is adjusted the aperture in the slide, and into this is introduced the axis so that it likewise passes through the ring and enters the table.

4. A fine and strong thread, of silk for example, capable of undergoing a pretty strong tension, and as long as the size of the table will allow, but at all events longer than the large rule. This thread is attached by one end to the ring just mentioned, and, by the other end, to a sort of thumb-tack, which serves to tauten it, as may be desired, on the table This thread gives an accurately straight line for regulating the instrument by. When it has performed this duty, and the instrument has been regulated, it is coiled up to the left of the iron weight without disturbing the ring.

5. Another and coarser thread, which serves to lift the pencil when it is not to mark, and which is fixed by a slip-knot to a small hook soldered to the pencil-holder, passes over a small pulley, and winds around one of the operator's fingers, after traversing the two rings on the bars, C and D'.

6. Disks of lead or other metal, having a hole in the center, and serving, when placed in proper number upon the stem of the pencil holder, to press the pencil against the paper so as to obtain a line of more or less strength.

To use the instrument, the paper is affixed by thumb-tacks to the table, and the design to be copied is placed under the style, to the left if it is to be increased, or to the right if it is to be reduced. Nothing is easier than to interchange the positions of the style and pencil, these latter being held on their identical supports by set screws only. It is only necessary to unscrew the latter and remove the slides with which the style and pencil are connected and change one to the right and the other to the left.

The silk thread that serves to raise the pencil holder passes through small rings at the upper extremity of the coupling bars, toward their axes, runs to the bottom of the bar that supports the style, and winds around one of the fingers of the operator. The latter, by bending his finger inwardly or

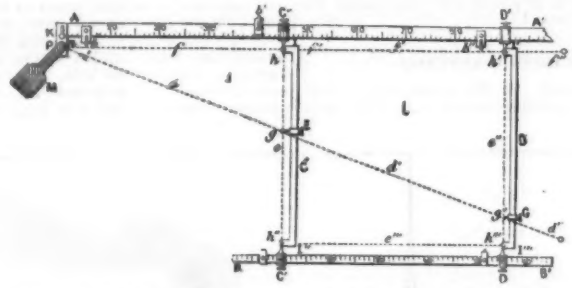


FIG. 2.—GEOMETRICAL DETAILS OF THE APPARATUS.

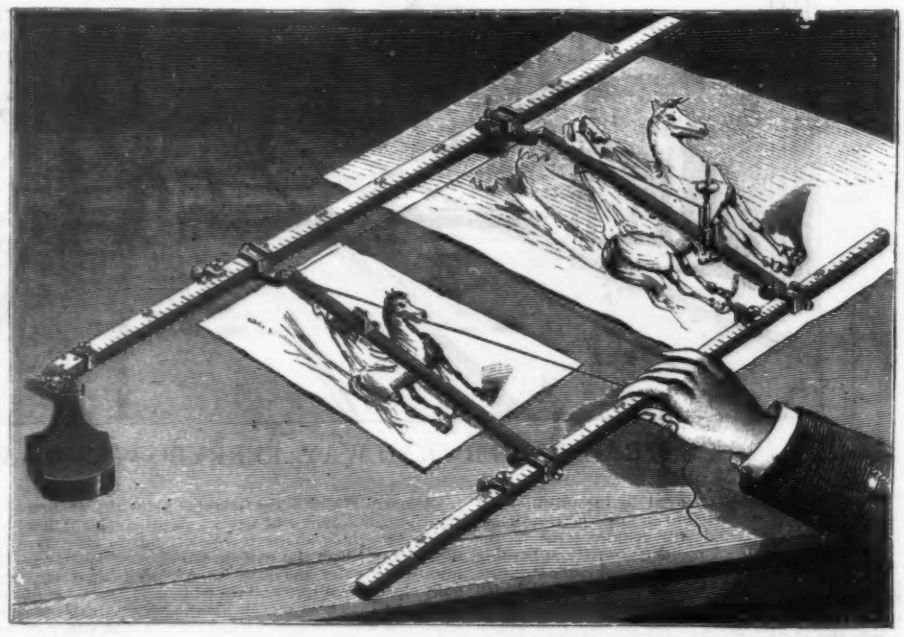


FIG. 1.—MODE OF USING MERESSE'S TACHYGRAPH.

outwardly, lifts the pencil or lets it fall. If he has to draw a continuous line or contour, he has only to allow the pencil to act, while at the same time he follows the lines of the copy with the style a little above it in order to prevent its being injured by the point touching it. It is scarcely necessary to say that this delicate operation requires care and attention, since the pencil faithfully reproduces the very errors of the style.

Two different styles—one of them vertical and the other horizontal—may be adapted to the instrument, just as the operator prefers.

When drawings containing many straight lines are to be reproduced, such as architectural, geometrical, etc., the most convenient and practical process consists in indicating the apices of triangles and the extremities of lines by a point, and then tracing these latter directly by means of an ordinary ruler; for it must not be thought that a straight line of a certain length can be drawn by guiding the style alone. It is not difficult to see that, with a little exercise, more can be learned on this subject than we can teach.—*La Nature.*

CORRECTING LEANING WALLS.

THE great power possessed by a freezing and thawing bank of earth in pressing against and finally overthrowing a wall of masonry is familiar to many of our readers. The earth in contact with the wall expands by freezing, and the force which will split a solid cast iron kettle crowds the wall a short distance inward. This process continuously repeated

FIG. 1.

becomes more powerful in its effect than a battering ram. We may find all through the country the walls of barn basements thus crowded aside till thrown largely out of a vertical position. In one case, the thrusting force of a bank of earth had displaced a barn wall, against which it rested, nearly a foot, the movement carrying the timbers of the barn with it and producing a corresponding leaning of the wall on the opposite side of the building. The remedies in this case were thorough underdraining at the base of all the walls; crowding the outer wall to its former position by means of jack screws attached to strong timbers, both resting on larger timbers placed like leaning props outside. The lower and outer ends of these timbers were secured by resting against the sides of large timbers sunk horizontally into the soil with the earth beaten compactly about them. A part of the wall, when replaced, was built over again, and a part was sufficiently substantial as it stood. A trench was dug down between the sloping and pushing bank and the wall against which it had rested, and this trench, with good bottom drainage, was filled with small and broken stones. With this arrangement the frost could no longer act on the wall, and it has been subjected to no movement since.

We had occasion recently to examine the walls of a barn which had been nearly overthrown in the way just described, but which had been repaired in the most substantial manner, on a farm belonging to a distinguished engineer, the work being done under his direction. Fig. 1 represents the inclined position of one of the walls, against which the

FIG. 2.

freezing bank of earth had been long successively acting by small thrusting movements. Fig. 2 is its appearance when repaired. An ample trench was first cut down next to the bank face. Six powerful jack screws were then employed in connection with the necessary sloping timbers, for placing it in an erect position. An additional wall was then built against the inner face of the first, a part of which was removed to admit the necessary binders. The whole was thus made into a very substantial piece of masonry, three feet thick at bottom and sloping upward, the stones being laid in water lime cement. The trench was filled with broken stone and gravel, and the work was thus completed. A simple inspection was sufficient to convince any one that there was no further danger of displacement.

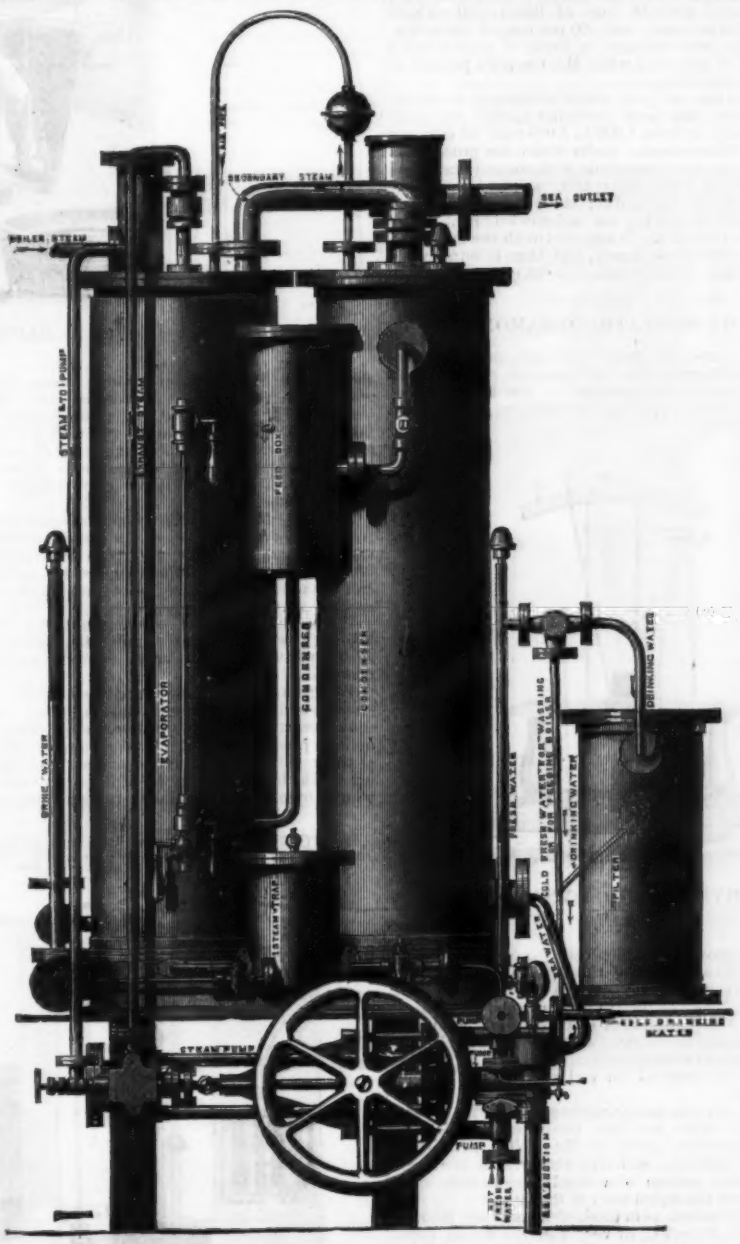
There are many farm buildings through the country whose foundations have been more or less distorted in the same way, and they may be restored by similar means.—*Country Gentleman.*

TERRA COTTA AND BRICK.

The difference between terra cotta and brick is one of degree rather than of quality. The original material is clay, which is chemically a hydrated silicate of alumina with less than one-half of alumina, or only 40 per cent, against 50 per cent of silica and 10 per cent of water. But the clay that is formed into terra cotta is the same clay as to constituents, only that the constituents are of differing characteristics. The sicilica in the ordinary brick clay is in grains, appreciable to the eye or the touch; while the clay suitable for terra cotta is a mass in which the silica cannot be distinguished from the aluminum. There is also a less proportion of silica in the clays which are adapted for terra cotta work and the finer qualities of pottery; but the quality of the union is similar. Only it must be noticed that while a high heat will vitrify the ordinary plastic clay, it will merely consolidate that which holds a less amount of silica and in a finer condition. And it is not necessary that terra cotta (burned earth) should be of a red hue to entitle it to its name; for true terra cotta can be of a cream color, the adventitious color of the red product being due merely to the presence of oxide of iron.

SALT WATER DISTILLING APPARATUS.

NORMANDY'S Patent Marine Aerated Fresh Water Company, Limited, show, in the Engineering and Metal Trades Exhibition, London, several distilling apparatus for producing cold drinking water from sea water—a compact arrangement of apparatus occupying a space of 40 in. by 22 in., and of the size generally supplied for torpedo boats for converting sea water into good, cold drinking water, and at the same time producing hot fresh water for feeding the boilers, so as to replace that used for distilling purposes, is illustrated in elevation below. It yields 175 lb. of fresh water for every 100 lb. of boiler steam used, the extra 75 lb. being gained by secondary evaporation of the sea water used for condensing. The apparatus is shown in operation with sea water, producing two streams of fresh water, the hot one being the condensed boiler steam, and the cold one, equal to 75 per cent. of the other, being the fresh water for drinking purposes, or for supplying to the boilers to make up the loss from leakage, in place of using sea water. The construction will be readily understood by reference to the engraving. The condensing sea water is pumped into the condenser and surrounds the cooling tubes, but instead of going to waste, part of it passes through a self-acting feed box into the evaporator, where it condenses the exhaust steam from the pump, so giving the hot water for feed purposes. In condensing the steam, the sea water itself becomes heated to such an extent that considerable distillation takes place, and this secondary steam continually passes into the condenser, from which it issues as fresh cold water, having been condensed by the cold sea water surrounding the cooling tubes. The steam pumps are three in number, one for circulating the condensing water, one for forcing the hot fresh water into the boiler or hot well of the engine, and one for delivering the cold fresh water into the tanks or wherever it is required. Provision is made for aerating the drinking water, and for the automatic discharge of the concentrated brine, and also for mixing, when desired, the hot and cold fresh water. A larger machine of the same kind, such as is used by the Royal Mail Steam Packet Co., is also exhibited, as well as smaller apparatus for producing drinking water only.—*The Engineer.*



APPARATUS FOR DISTILLING SALT WATER.

LIMED COAL FOR GAS MAKING.

By J. ALFRED WANKLYN.

THE experiments of the President of the Gas Institute, which were mentioned in the address delivered by him at the recent meeting in Sheffield, have bought into prominence one of the most remarkable features of Cooper's new process of gas making. Mr. Paterson found that when coal is limed in the manner recommended by Mr. Cooper, there is a gain of 13 per cent. of tar over the ordinary process of carbonization without lime. This observation is especially welcome, inasmuch as it runs counter to prevailing prejudice. Gas engineers are apt to take a too mechanical view of the process of carbonization; and in many quarters the notion prevails that an increased yield of tar is impossible, except at the expense of the gas. In such quarters one hears it stated that the tar is increased when carbonization is performed at low temperatures, and when the make of gas is very small; but the possibility of getting a good yield of gas and at the same time an increased yield of tar is looked upon as an absurdity. That which has been held to be an absurdity, Mr. Cooper claims to have accomplished. By liming the coal as directed in his specification, Mr. Cooper claims to have so modified the process of carbonization that the tar is increased without either diminution of the quantity or deterioration of the quality of the gas.

In the account of his experiments, Mr. Paterson expressly mentions that the yield of gas from the limed coal (which furnished the excess of tar) was practically the same as the yield from the unlimed coal. I will, on the present occasion, describe an experiment on a manufacturing scale—viz., on the entire make of a small gas works—showing a result of the same description as that announced by Mr. Paterson.

In this experiment, which was performed last September at a small gas works in the neighborhood of London, 100 tons of a mixture of Wigan and Silkstone coal were divided into two equal portions of 50 tons each. One portion was carbonized in the usual manner, and the entire yield of tar was measured, and a sample sent to my laboratory for examination. The other portion was carefully limed with 2¼ per cent. of quicklime previously slaked; and then it was carbonized, the tar measured, and a sample sent for examination. The yield of gas and the illuminating power were observed in both instances. The results were as follows:

Unlimed Coal.—50 tons of coal carbonized; tar, 560 gallons; specific gravity at 63° Fahr., 1·1645. Therefore the weight of the tar was 6521·2 lb.

Limed Coal.—50 tons of coal carbonized; tar, 590 gallons; specific gravity at 63° Fahr., 1·1723. Therefore the weight of the tar was 6916·6 lb.

From this it follows that there was a gain of 6·1 per cent. of tar when the coal was limed. At the same time the yield of gas was maintained, and even increased to a slight

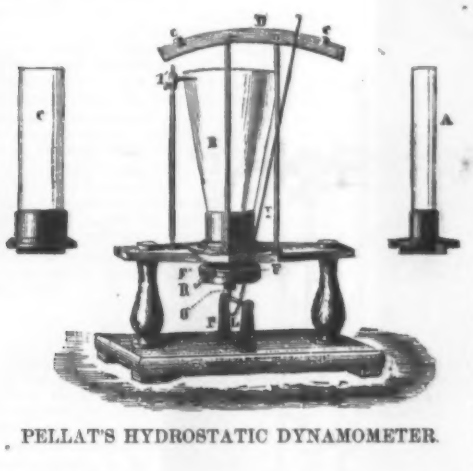
extent; the figures being 10,940 cubic feet at 16·6 candle gas per ton of the unlimed coal, and 11,180 cubic feet of 16·71 candle gas per ton of the limed coal. If a calculation be made, it will be seen that the gain in make of gas by Mr. Cooper's process is 2·02 per cent,; and the result of a working on the entire make of gas at the small works is thus seen to be a gain of 6·1 per cent. of tar, and 2.2 per cent. of gas by the employment of the process.

The next point is the gain in ammonia consequent on liming. The evidence showing this gain is of a most varied character. First, in the order of time, there are the results obtained in my own laboratory, which I have summarized by saying that they show that coal limed as Mr. Cooper directs is capable of yielding, on carbonization, from 12 lb. to 15 lb. of ammonia per ton of coal. I believe this will be realized in practice when the liming is done in the right way, and when the gas liquor is properly collected and preserved. Then there are results obtained by three different gas managers at three separate works. In one set of experiments, some of which I witnessed myself, a gain of rather more than 30 per cent. of ammonia was shown. In another experiment, at a different works, there was a gain of a little less than 30 per cent. of ammonia. A third observer—viz., the (now) Past-President of the Gas Institute—has recorded a gain of 20 per cent. of ammonia. There are also two experiments on a thoroughly working scale—viz., on the entire make of two small gas works, in which 50 tons of unlimed coal were compared with 50 tons of limed coal—which showed gains of 35 per cent., and 100 per cent.of ammonia. Viewed altogether, the evidence in favor of there being a substantial gain of ammonia when Mr. Cooper's process is resorted to is overwhelming.

In the course of the half year which is drawing to a close, Mr. Coper's process has been gradually applied on a very large scale—namely, to from 1,600 to 3,000 tons of coal per week. But the circumstances under which the process has been introduced are not compatible with measurements of the gain of ammonia. An opportunity has, however, been afforded of placing in the market many thousand tons of the new coke, and of getting an acknowledgment of its merits, which are that its use is attended with the evolution of little or no sulphurous fumes, and that it burns with greater readiness than ordinary coke.—*Jour. of Gas Lighting.*

PELLAT'S HYDROSTATIC DYNAMOMETER.

IN elementary courses of physics two apparatus are usually employed for showing that the pressure exerted upon the bottom of a vessel is independent of the latter's form, these being the Pascal apparatus modified by Masson, and the Holdat apparatus.



PELLAT'S HYDROSTATIC DYNAMOMETER.

All professors know how difficult it is to perform the experiment well with the former of these, because of the leakages and adherences that occur between the cut off and the base of the ring. As for the Holdat apparatus, its indications are not very visible from a distance; and, besides, it may appear whimsical to youthful minds to see a surface of mercury employed as the bottom of a vessel. In brief, this instrument is rather adapted for verifying the law of communicating vessels.

The hydrostatic dynamometer represented in the accompanying cut, and which has been constructed by Mr. E. Ducretet, after directions given by Mr. Pellat, permits of showing without difficulty, and very visibly, that the pressure upon the solid bottom of a vessel depends only upon the height to which the liquid rises in the latter.

The instrument consists, as in those of Masson and Holdat, of three vessels, A, B, and C, of very different forms, capable of being screwed to the same cylindrical brass ring, F F'. This latter is closed below by an elastic rubber disk, which is secured to its sides and held between two horizontal brass disks whose diameter is slightly less than that of the ring. The upper disk thus forms the bottom of the vessel; and, owing to the rubber membrane, while leakages are avoided, a certain amount of mobility is allowed it. When any pressure whatever, particularly one produced by a liquid poured into the vessel, is exerted upon this bottom, it becomes slightly depressed. Such slight movements are greatly amplified by a lever, O L I, analogous to the one employed in the dial pyrometer. The longer arm, I, of this lever moves so much the further along the dial, D, in proportion as the pressure upon the bottom of the vessel is greater, and, with the same pressure, takes the same position. Two small slides, C C', permit of the successive positions of the index being marked when the vessel is empty and when it is filled up to a certain height marked by the index, I'.

It appears to us useless to dwell upon the manner in which the experiment is performed. We need only say that a cock, R, permits of the water being drawn from the vessel before the latter is unscrewed and replaced by another. In measure as the liquid flows out, the index, I, is observed to move backward regularly, thus indicating that the pressure is diminishing upon the bottom of the vessel.

In very elementary courses a description of the mechanism of the amplifying lever, which is so simple, may be dispensed with, and it may be merely shown that on pressing with the finger upon the bottom, or on loading it with weights, the needle moves forward upon the dial so much the further in proportion as the pressure is stronger.—*La Nature.*

GLASS BLOWING BY MEANS OF COMPRESSED AIR.

THE shaping of glass, which has previously been melted and brought to a proper temperature (always less than that necessary for the combining of the elements that compose it), is effected by two very distinct processes—casting and blowing.

The Casting Process.—The pot full of melted glass is taken from the furnace and its contents are poured upon a table, and the glass is then spread out, by a cylinder of proper weight, into a sheet whose thickness is regulated by the height of the bars or ribs that surround the table. This is the way in which plate glass is made.

When the quantity of glass to be worked up is small, it is removed from the pot with a ladle and poured upon the table or into a mould that gives it the desired form. This is the process employed for making pieces for lighthouses, glass in relief for windows, sky-lights, etc. Moulded drinking vessels of the kind called "pressed glass" are made by taking up some glass from the pot with an iron rod, heated at one of its extremities, allowing it to fall into a mould having the external form and dimensions of the article to be made, and pressing into it a core or plunger of the proper size and shape.

Process by Blowing.—The proper amount of glass is taken from the pot with a tube, which is expanded at one extremity, and which has previously been heated to a temperature of 600°. Then the workman applies his mouth to the other end of the tube, and forces his breath into it with the necessary amount of pressure.

We do not know that any experimental trials have been made with a view of determining the pressure produced by such expiration from the lungs, so we have been obliged to make some.

The maximum pressure produced under such circumstances, and in a very short time, may reach 150 grammes per square centimeter. In practice, the blowing is performed under a pressure of from 5 to 30 grammes. We have arrived at this result in a very simple manner, and that is by adapting to the blowing tube an ajutage provided with a cock, which, by means of an elastic rubber tube, we put in communication with a water or an open leg pressure gauge at the time the blowing is being done. (Fig. 1.)

The operation of blowing is hard on the workman, not only because of the muscular effort that it imposes on him, but also because of the great volume of air that he has to draw into his lungs within a very short space of time. Such defective conditions are further aggravated by the high temperature and dry atmosphere of the place in which he has to move, and this makes him liable to special affections, such as ulceration of the lips; deglutination and distention of the cheeks, leading to the formation of mucreous patches—an indication of an alteration in the mucous membrane; fistulas of the salivary canal; and a predisposition to emphysema and hernia.

As the blowing is very often performed by young children during their development, the results are still more disastrous.

In order to overcome these inconveniences, a series of apparatus has been invented with a view to securing a substitute for blowing by mouth. The oldest and best known of these is the Robinet piston, which was invented by a workman of Baccarat, whom sickness had robbed of a part of his means. This apparatus, owing to its dimensions and *modus operandi*, is only capable of being used for manufacturing articles that are relatively small. More recently, other apparatus have been invented, which have always had the defect of requiring on the part of the workman an accessory effort that counterbalanced the advantage they offered in the doing away with the blowing by mouth.

By our process we effect the compression of the air mechanically, and distribute it to each workman, so that he has no longer anything further to do but to expand it at his will by means of apparatus that we place in his hands.

Pressures necessary to effect the Blowing.—The temperature to which glass must be raised, in order to blow it, varies according to its nature, whether it is basic or acid, aluminous or non-aluminous.

On another hand, the pressure of air within the interior of the article in course of manufacture is in inverse ration to the temperature to which it is carried. The initial pressure to be exerted at the cold extremity of a tube of given length and section is, itself, in inverse ratio to the time that the glass will take to lose its malleability.

The cooling of the glass, and consequently its diminution in malleability, will take place more or less rapidly according to different causes, which are: its capacity for heat; its density; the size of the article to be made; its thickness; and its mode of manufacture, whether it be blown or moulded. It results from this that the conditions that must be fulfilled in the organization of a system of mechanical blowing are the following: (1.) Disposal must be made of pressures varying in intensity. (2.) For any special kind of manufacture the pressure of the air introduced into the blowing tube must be slightly greater than, or at least equal to, the maximum pressure which may be necessary at a given moment; and such pressure must be constant in the piping in which the air is stored. (3.) By means of the apparatus placed at his disposal, the workman must be able to produce a varying expansion at will.

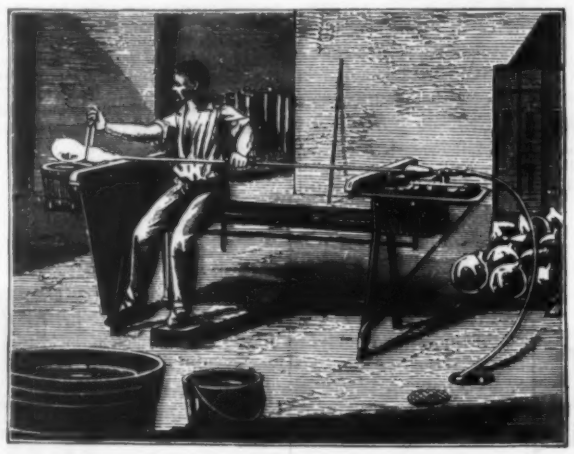


FIG. 1.—BLOWING GLASS WITH COMPRESSED AIR.

FIG. 2.—APPARATUS FOR MOULDING BY COMPRESSED AIR.

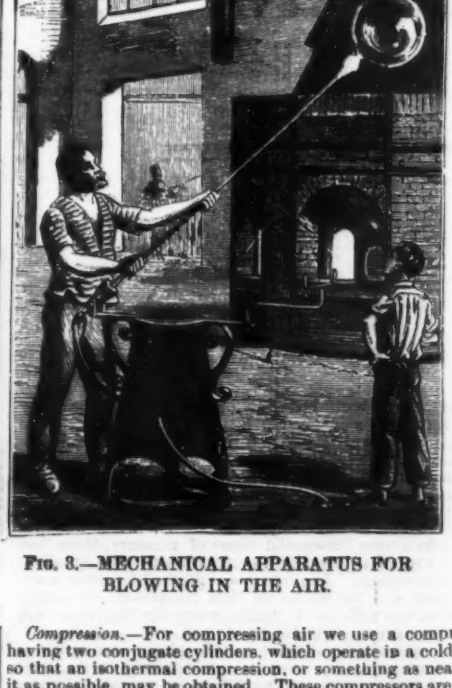


FIG. 3.—MECHANICAL APPARATUS FOR BLOWING IN THE AIR.

Compression.—For compressing air we use a compressor having two conjugate cylinders, which operate in a cold tank so that an isothermal compression, or something as near like it as possible, may be obtained. These compressors are actuated by the steam engine belonging to the works, and a small portable Belleville engine stands always ready to take the place of the principal motor in case of accident or repairs.

The compressed air is stowed up it twelve steel-plate reservoirs, tested to 4 kilogrammes, and having a capacity of 670 cubic decimeters each, or a total capacity of 8,000 decimeters. These reservoirs are arranged in groups at the end of the furnace hall, are connected with the same conduit, and can be isolated by means of a cock. They are charged permanently with air compressed to 3 kilogrammes per square centimeter. They serve as accumulators for current operations, and, in particular, for night work, and have to suffice for 12 hours' work. The piping is of lead, and is 26 millime-

ters in diameter. (Fig. 4.) Connections are made directly with the high pressure conduits for articles of very large size.

For blowing ordinary drinking glasses a special piping communicates with the high pressure cylinders through the intermedium of a mercurial regulator, which expands the compressed air to a pressure of 170 to 200 grammes per square centimeter. This piping, which is of cast iron and 125 millimeters in internal diameter, is suspended beneath the floor of the furnace hall. The air compressed to this degree is stored in 4 reservoirs of a capacity of 670 cubic decimeters. The total volume is 4,000 cubic decimeters.

Along this piping there are twenty coupling screws, analagous to those used on water pipes, which are arranged around the furnaces at the most convenient places. The proper working of the apparatus is shown at every instant by a high pressure gauge, and a water and an open leg steam gauge.

As a consequence of these arrangements, the different systems of piping can be kept under constant surveillance.

Distributing Apparatus.—The difficulty in applying blowing apparatus to the glassworker's tube resides in the fact that the workman is obliged to rotate the latter continuously in order to keep the piece of glass that is being worked in an axis that is sensibly the same as that of the tool that supports it. The position of this tube varies according to the kind of work being done; so, in order to satisfy such different conditions, we have constructed three types of apparatus to be used; (1) according as the workman is making the glass by revolving it according to a horizontal axis; (2) revolving it according to a vertical axis, the glass being under the tube; or (3) revolving it according to a vertical axis, the glass being above the tube.

These apparatus, moreover, are based upon the use of an air-pipe, into which the workman fits his tube, and of an automatically closing cock that he actuates either with his hand or with his foot through the intermedium of levers, so as to produce the expansion that he requires.

The first apparatus is the ordinary glass-blower's chair. (Fig. 1), which we allow its full dimensions. The second, which is called a "swan's neck" (Fig. 2), serves for moulding with the stationary or revolving mould. The third is used for blowing in the air such articles as balls, matrasses, etc. (Fig. 3). All these apparatus are movable, and are adapted to the coupling screws of the lower piping of which we have spoken. For the blowing of glass that is to be rolled a leather pipe is applied to the blowing tube by the boy who helps the workman; such is the case in the manufacture of tubes and of cylinders for window glass. In this case the compressed air is distributed by an inclined plane at the end of the hall, over which descend the distributing pipes.

Results of the Use of Compressed Air.—The advantages derived from the use of a compressed air are of several natures: It permits us, in the manufacture of drinking glasses, to entirely do away with blowing by the mouths of children, and, with very rare exceptions (mostly through inattention of the workman), with blowing by the mouths of adults.

It protects these latter, then, against the special affections that were brought on by the old method of blowing. There being less fatigue for the workman, he produces better work, and a greater quantity of it, and the articles are manufactured with greater precision. Finally, the use of our process permits of obtaining, without fatigue of our men, articles of dimensions that have been hitherto unknown, both as regards bulk and other dimensions, such as length and thickness. The limits that may be reached are governed only by the weight of the material operated upon. This process, moreover, is very elastic, since, in consequence of the successive expansions that the workman produces at will, the pressure may ascend from 5 to 3,000 grammes per square centimeter, and form objects having a capacity of from 2 to 1,700,000 cubic centimeters.—*Appert Brothers, in La Nature.*

A NEW PROCESS FOR THE SEPARATION AND RECOVERY OF THE VOLATILE CONSTITUENTS OF COAL.*

By T. B. LIGHTFOOT, M.Inst.C.E.

IN bringing the following paper before the members of the Society of Arts, my object shall be, first, to point out briefly the necessity that exists for some simple and inexpensive method of recovering the volatile products now almost universally lost in the coking of coal; then to describe the nature of the process recently invented by Mr. John Jameson, of Newcastle-on-Tyne, and the form of apparatus employed; and, finally, to give some particulars respecting the utilization of the recovered products, and some considerations as to the possible application of the system.

It will be premised that all here are acquainted with the general facts that coal consists of a solid or carbonaceous component, and a gaseous or chiefly hydrogenous one, and that the process of coking is undergone for the purpose of driving off the gaseous portion, and leaving behind an almost pure, solid carbon; also that the hydrogen, in being driven off, carries with it some carbon in combination; that part of the hydrogen, by combining with the nitrogen of the fuel, forms ammonia; and that some of the hydrocarbons, as well as ammonia, are, to a great extent, condensable at the ordinary temperatures, and form most valuable, and much sought for, articles of commerce.

Seeing then that this is the case, it surely must be a matter for surprise as well as regret that, at the present time, nearly the whole coke manufacture is carried on under such circumstances as to prevent the utilization of the volatile products in any way whatever; moreover, that these valuable articles of commerce are blackening and defacing the surface of the country. In some cases, it is true, the fumes have been collected, and passed under a boiler for generating steam, the products of combustion escaping from a high chimney; and, recently, close distillation has been successfully carried out in the ovens of Mons. Carves; but I am certainly within the mark when I say that the gaseous products of nearly the whole of the 20,000,000 tons of coal annually coked in this country are absolutely wasted, and set free to injure vegetation. A fair idea of the meaning of such a statement may be gathered by considering the loss from this cause actually taking place in one of our greatest industries, that of pig iron. From published returns, it appears that last year there were 575 furnaces in blast in the United Kingdom, producing 8,450,000 tons of pig iron. In the majority of these furnaces the fuel is coke; but in a considerable number raw coal is still used, and of these, in only two cases, the volatile products are condensed, and recovered by a process introduced by Mr. Ferrie, though I believe the system is now being extended to fourteen other furnaces. With this exception, and neglecting the few ovens on the Carves and on the Jameson systems at present in operation, we may take it that the condensable volatile products of all coal used in the manufacture of pig iron are entirely lost, while, in those cases where the coal has been previously coked, much of the gas is wasted likewise. Deducting, therefore, the 36,500 tons made in the two Ferrie furnaces from the total production, and taking an average of 34 cwts. of coal per ton of pig iron, we find that for this one industry alone as much as 14,302,000 tons of coal are being thus wastefully dealt with, representing, for oil and ammonia, at present prices, a loss of some £2,300,000 a year, or about 5s. 6d. per ton of pig iron produced.

From this brief consideration, I think it will be at once conceded that a real necessity exists for a process in which the constituents of the coal will be economically separated and collected, so as to be used in the most beneficial manner. But, it may be asked, if the want is so great, has such a process not existed for some time, and are there not very good practical reasons to prevent its adoption, either on the score of deterioration in the quality of coke produced, or from some other cause? To this it may be answered that, during the last ten years, patents have been taken out for apparatus to accomplish the object in view; but in this country, at any rate, none of them have had extended application. It seems as if coke manufacturers were only now awakening to the fact of their want of economy, possibly because, in recent years, prices have been so low, and competition so keen, that profits have been cut down to the smallest possible fraction, if indeed in some cases they have not altogether disappeared. Another consideration of obvious importance, is that no process involving the entire rebuilding of the coking ovens, or even their alteration to any great extent, was likely to obtain speedy adoption, for all manufacturers are naturally averse to a wholesale replacement of their plant, which means a large increase in capital invested, and upon which interest must be paid.

Looking at the various processes patented for the recovery of the volatile products, prior to the working out of Mr. Jameson's plan, it may be stated that they all involved the use of close ovens, and were of two distinct characters, viz., those in which distillation was to be carried on in an oven or retort, externally heated by the gas after being deprived of its more easily condensable constituents, and those in which the gas was to be used inside the oven itself over the charge, for giving the heat required in coking. Of these, so far as I am aware, externally heated ovens have alone been successful in practice.

Now, without entering into any detailed criticism of this system, which doubtless gives good results, I must just mention what appear to me to be its principal objections, in order that I may the more easily show in what respects Mr. Jameson's plan is, in my opinion, to be preferred for the treatment of large quantities of coal.

A great objection to externally fired ovens is their excessive first cost, and, on account of their special form, it is quite impossible to alter existing plant for the carrying on of the process; then again, there is a considerable waste of heat, owing to the high temperature which must be maintained within the flues, a consideration which will, perhaps, be best appreciated by remembering that in ordinary gas works, with externally heated retorts, about twenty-six per cent. of the total coke produced is consumed for heating purposes; and finally, there is the cost of repairs, which cannot fail to be greater than usual, on account of the number of flues, all exposed to intense heat, and the practical difficulty of having to quench the coke after withdrawal, a proceeding which, as is well known, is apt to leave an excessive amount of water in it when sent out to the purchaser. Added to this, the beehive oven is that which is generally acknowledged to be not only the easiest built and kept in order, but also to produce the highest quality of coke. At the same time, it cannot but be admitted that, in certain cases, where no use could be made of the gas, it might be more economical to dispose of it for heating the charge rather than let it go to waste; but this, I need scarcely point out, should be a very exceptional circumstance, and one which could hardly exist at all in this country, if the value of gas, as a heating agent, was more fully recognized.

In applying Mr. Jameson's process, it is not necessary to

FIG. 4.—GENERAL VIEW OF MESSRS. APPERT BROS.' GLASS WORKS.

* A paper lately read before the Society of Arts, London.

rebuild the ovens, the form being retained precisely as in use at the present time, and the extraction of the gases accomplished either by inserting in the floor a couple of perforated iron pipes connected with an exhauster, or, preferably, by forming the bottom with perforations in the fire-clay quarls themselves, and applying a slight suction through all the openings. The process is, therefore, immediately applicable to the whole of the ovens treating the 20,000,000 tons of coal annually coked, and if this were done, there would be obtained from this source alone ammonia corresponding to at least 90,000 tons of sulphate, at present worth more than £1,250,000. The oil would also be worth some £2,000,000, and the gas, at even 3d. a thousand cubic feet, would come to £2,500,000, making in all the enormous total of £5,750,000 as the commercial value of products now being entirely wasted in the coking process.

The diagrams show an ordinary beehive oven adapted to the recovery process. The only alteration is in the floor, which, with the exception of the solid margin, consists of perforated fire-clay quarls laid on a bed in which are formed the passages, these passages communicating with the main pipe by means of the branch, in which is an ordinary screw-down valve or water-lute connection for shutting off the oven when not in operation. The object of the arrangement is to draw off the gases at the bottom by producing a slight suction in the main pipe. It is, therefore, important to have a secure and tight foundation, so as to avoid drawing in air and vapor from the surrounding ground, and for this end it is well to have a double layer of bricks set in hard pitch, at such a distance down as not to be exposed to undue heat, as well as to have a good damp-proof course, such as is laid in the foundations of a dwelling-house.

A bench of twenty ovens with recovery plant is also shown. The main pipe, with which each oven is connected, extends along the entire length underground, with a fall toward the condenser, which, in its simplest form, is a range of cast-iron pipes exposed to the cooling action of the atmosphere, or surrounded by water in cases where it can be obtained without much expense. The condenser discharges through a lute into the separator, a pipe being carried on to the exhauster or fan, driven by the engine, the speed of which can be regulated to obtain the proper suction required at the different periods of the operation. From the exhauster, the gases, deprived of their condensable constituents, may be taken where desired, but the diagram shows them discharged under the boiler for generating the steam required by the engine. The liquors, being delivered into the separator, arrange themselves according to their specific gravities, and a rough divison is therefore made by running off the crude oil into one tank, and the ammoniacal liquor into another.

The cost of altering existing ovens to Mr. Jameson's plan is stated to be from £15 to £20 each, this sum including all requisite connections and condensing-pipes, which are of the simplest possible description. Bearing this in mind, as well as the fact that the increased cost of working the new system does not amount to one penny per ton of coal, it will be seen that not only is there no impediment, on the score of outlay, to prevent the immediate adoption of the process, but that the sale of recovered products is likely to become an exceedingly profitable undertaking.

The action is as follows: The ovens are charged from the top, and in the usual manner ignited. A suction equal to about one inch of water is then applied by the exhauster through the pipes to the bottom of the charge, and the products of distillation continuously drawn off, the charge, to all appearance, burning in the usual way. During the process, the effect is produced of a gradually increasing heat, commencing at the top, and passing downward slowly to the temperature of intense incandescence in every part of the oven. In the old system, the gases and vapors evolved at a comparatively low temperature percolate through the more highly heated upper layers, and there suffer decomposition; but in Mr. Jameson's process, while the operation of coking is, to all intents, going on in the ordinary way, the gases and vapors are withdrawn as they form and any decomposition effectually prevented. In point of fact, from the moment of formation they are actually cooled, heat being abstracted by the unchanged portion of the charge toward the bottom of the oven, this being shown by the circumstance that, when taking away about 200 cubic feet of gas per hour per ton of coal, and continuing this withdrawal for about sixty hours, the temperature of the pipe, on emerging from the ground, does not average more than 180° Fahr.

Owing to the supply of air being admitted at the top, the upper surface of the charge suffers combustion, so supplying most of the heat requisite for coking. The advantage of thus utilizing a portion of the highly heated coal charge itself, is twofold. In the first place, by using carbon as the heating agent, a thermal intensity is gained which cannot possibly be reached by the combustion of the gas, while, in the second place, the average quality of the coke is improved. All those acquainted with the making of coke in the ordinary way will be aware that the top layer is extremely porous and inferior, from being formed at a low heat, in a comparatively cool freshly charged oven. It is this upper surface that is burnt off in the Jameson process, and so an objectionable element is got rid of.

From what has been said, it will be seen that the production of coke in the Jameson ovens must necessarily be somewhat less than with close distillation. This difference amounts to not more than 2 cwt. of coke per ton of coal treated, in favor of externally heated ovens. On the other hand, however, it is claimed for Jameson's process that the average quality of coke is better, and of course, as a set off against the lessened production, there is the saving in valuable gas, which may be used for heating, for giving power, or for lighting in connection with such burners as the Lewis or Clamond, which depend for their illuminating power on the incandescence of platinum or some other incombustible material, instead of on the fine particles of carbon deposited in the flame itself. There are also advantages for the Jameson system on account of lessened first cost, and its adaptability to ovens now in existence. These are most important factors, and though it is impossible to place any average money value upon them, they must not be overlooked when considering the merits of the new process.

The volatile products are the products of distillation of coal at a low temperature, and are to be regarded as the vapors of various hydrocarbons of the paraffin series and of ammonia saturating an atmosphere consisting chiefly of hydrogen, nitrogen, and carbonic oxide. Up to the present time, with the imperfect condensing apparatus employed, the data indicate that an average yield of about eight gallons of crude oil, and ammonia equal to a production of ten pounds of sulphate, may be expected per ton of coal; but with improved condensing arrangements, there is no doubt that a considerable quantity of vapors, especially ammonia, now lost, will be recovered. The oil is a crude paraffin of specific gravity about 0·96, and contains a considerable quantity of solid paraffin of high melting point; but both quality and quantity vary so much with the kind of coal under treatment that on this point it is impossible to give more than a general idea. The following table gives a few of the results obtained per ton of coal treated:

Kind of coal.	Gals. of crude oil.	Ammonia estimated in pounds of sulphate.
Shiremoor	13·	9·87
Brancepeth cannel	12·2	6·00
Longhirst, small	9·28	17·78

The following may be taken as an average analysis of the crude oil:

	Per cent.
Lubricating oil	39·5
Burning oil	37·7
Paraffin scale	13·5
Tar and loss	9·3
	100·0

In reference to the question of condensation I should like to draw attention to a process which, though successfully tried on a practical scale some years ago, has, to my mind, not yet received the attention it deserves. I refer to the compression of the gas and vapor, and the subsequent cooling of them when under compression; first, by an external application of water, and then of the gas itself, cooled much below its original temperature by expansion behind a piston after its passage through the condenser under compression. This method formed the subject of an interesting paper, read before the Chemical Society of London, in 1875, by Mr. J. J. Coleman. It will be easily understood by remembering that, under constant temperature, an increase in pressure decreases the capacity of a given weight of gas for holding vapor in solution. In a saturated mixture, therefore, a vapor will be condensed and deposited, either by an increase in pressure or a reduction in temperature. The process referred to accomplishes both, and by its means the volatile products, after being treated by all ordinary condensing apparatus, may be made to yield liquors of low specific gravities and boiling points which might be valuable as local anæsthetics, or as the refrigerating media in ice-making machinery.

Reference should be made to the method of fractioning, for the purpose of getting an automatic separation of the products, according to the temperatures of liquefaction, without future distillation. This is now being carried on at Felling by Messrs. H. L. Pattinson & Co., who, by placing discharge lutes at five different points in the condensing pipes, are obtaining liquors of specific gravities from 0·945 to 1·015. Another mode of separation is one by which a series of five gas mains is provided, and connections made so that the gas may be passed into each main in turn, for the purpose of securing some difference in the quality as well as a fractional separation of the by-products. With this arrangement, the discharge of gas is, every twelve hours, or at other convenient interval, passed into a different pipe for separate condensation, all the freshly charged ovens delivering into the first pipe, and so on through the series, according to the time which has elapsed since the commencement of distillation. Suction being applied through the last main during quenching, the pipes would be cleared of coherent dust and oil, and a considerable quantity of carbonic oxide and hydrogen obtained, as well as ammonia, which would otherwise have been wasted in the quenching water.

Mr. Jameson's process is in operation at the Felling works of Messrs. Hugh L. Pattinson & Co., and at the Page Bank Colliery of Messrs. Bell Bros., Limited, and is at the same time being introduced in the works of the Weardale Iron Co., and at some collieries in Northumberland. A number of experiments have been carried out by Mr. Lowthian Bell, F.R.S., to test the value of the system, both in regard to the yield and quality of coke, and the value of the recovered products, and further investigations are now in progress, as well as extension of the plant, so as to obtain sufficient coke for the entire working of a blast furnace.

An interesting application of an analogous patent, recently taken out by Mr. H. L. Armour, and the property of the Jameson Coke Company, Limited, has just been made in the case of a pit heap, at Seaton Burn Colliery, in Northumberland. A pit heap is a deposit for quantities of small coal and dust for which, as a rule, no market can be found, as well as for shale and iron pyrites met with in working the coal. These heaps are generally burning, and, in very many instances, give off so much smoke and dirt as to become a terrible nuisance to the neighborhood. This was the case at Seaton Burn; but by simply covering the heap with sand, and sinking a number of iron pipes connected to a main, in which a constant suction is maintained, all offense has been removed, and a stream of gas, yielding both oil and ammonia, is obtained. In this manner a worse than valueless property has been converted into a profitable one, and as the system is now being extended to large heaps at Kelvinside, near Glasgow, it is to be hoped that before long an end will be put to one of the greatest nuisances in colliery districts.

Though many of the members of this society are far better acquainted with the commercial value of the recovered products than I am, I must now ask you to let me say a few words as to the probability of such large quantities of oil, ammonia, and gas being profitably employed in the various industries which do exist and are likely to exist in this and other manufacturing countries.

At the present time, we depend for our supply of petroleum or mineral oil on two principal sources—the natural springs of Canada and the United States, and the distillation of bituminous shale, which has been developed in Scotland into an immense industry chiefly by the instrumentality of the late Mr. James Young. According to statistics published in *The Oil Trade Review*, it appears that in 1882 we imported from America 41,500,000 gallons of petroleum oil, and close on 6,000,000 gallons of petroleum spirit or benzoline. Toward the end of the year, the price of the oil, which for the first nine months had ruled about 5½d. a gallon, received a sudden rise, owing to reports reaching this country of the failure of the supply, and went up to as much as 7¼d. and 7¾d. a gallon. Without, however, attaching too much importance to the apparently failing supply of American oils in estimating the value of the English product, there can be no doubt that, at the present time, the average daily supply is nearer the daily consumption than it has been for the last five years, and it is in the highest degree probable that a permanent rise in price will before long be made, unless supplies come in from other sources. Some interesting particulars respecting the petroleum supply were given in the Society's *Journal* for September 1, 1882. With regard to the distillation of shale, few persons are aware of the immense magnitude of the works engaged in this industry. Altogether, in Scotland, there are about seventy oil works, at about forty of which crude oil alone is made; and I find, from particulars supplied by Mr. Thos. Scott, of Edinburgh, that there are two companies, each distilling 700 tons of shale per day, while two others each distill 400 tons, and five others, each 200 tons. Two firms each make 12 tons of paraffin candles per day. When it is remembered that something like 30 gallons of crude oil and ammonia, equal to 17 pounds of sulphate, are obtained per ton of shale, the importance of the industry and the great demand for the products will be apparent. Shale oil works also exist in Wales and Cheshire, but are now almost kept going in refining crude oil from Scotland on account of their supply of shale being exhausted. The great demand for crude oil is for the manufacture of illuminating and lubricating oils and solid paraffin, while from some are obtained the aniline dyes and other valuable products.

Illuminating gas of a very high quality is also made from the oil, and recently this application has received considerable development by Messrs. Rogers Brothers, of Watford, who have succeeded in producing an oil gas of great brilliancy and purity, which promises to compete commercially with gas made from coal in the ordinary way. The "Koh-i-noor" gas, as it is called, is made by injecting a continuous stream of oil into the end of a small iron retort by means of a jet of highly superheated steam. After flowing to the end of this retort, the stream returns through an annular space formed by a second tube placed outside the first, and externally heated by a coke fire. The gas is then conducted to a small washer, and requires no purification, as it contains neither sulphureted hydrogen, tar, nor ammonia. Its cost is stated to be about two-thirds that of coal gas for equal light, 300 cubic feet of 70-candle gas being produced from two gallons of oil; and a great advantage of the process is, that any existing gas works can be converted at a comparatively trifling cost, while, on account of the high illuminating power, a main of given size can transmit more than four times the amount of light that it does at present.

With regard to ammonia, it will be known to most of you that there has been rapidly springing up of late years a new process for the manufacture of soda, perfected by M. Solvay, of Brussels, and known as the ammonia process. In a recent paper, read before the Society of Chemical Industry of London, by Mr. Walter Weldon, F.R.S., it was pointed out that, though the commercial success of M. Solvay's process only dates from 1866, yet already 163,000 tons a year, or 23 per cent. of the total soda production of the world, is made by it, and that at the present time seven large works, capable of making about 7,000 tons of ammonia soda per year, are being built, while several others are in contemplation. In point of fact, the Leblanc process threatens to become extinct, unless some means are discovered for greatly lessening the cost of production. Now, notwithstanding all that can be done, the annual loss of ammonium sulphate in making the 163,000 tons of soda amounts to no less than 9,000 tons, so that, in this trade alone, it is evident that the demand for ammonia is likely to be very great and increasing. Curiously enough, in the same paper, Mr. Weldon not only pointed out that the Jameson process would be likely to supply the demand for ammonia created by the extension of M. Solvay's system, but that by its means it might be possible to so lower the cost of production of Leblanc soda as to enable it to successfully compete with that made with ammonia. In the Leblanc system, fuel, which at the present time is coal, amounts to as much as 350 per cent. on the weight of soda produced, while M. Solvay uses but 150 per cent. It was, therefore, suggested that the Leblanc soda makers should entirely cease to use raw coal as a fuel, and should convert all their coal, except that used for mixing in the black ash process, into coke, collecting for sale the oil and ammonia, and utilizing the gas for heating purposes. If this could be done, and duff, or very small coal, used for coking, the soda maker would virtually obtain his fuel for nothing, as the value of the recovered products would cover the original cost of the coal, and, in some cases, the expense of coking as well.

Turning to agriculture, it is evident that now that the guano deposits are becoming exhausted and poor in quality, the demand for artificially produced manures will increase year by year. In a letter from Dr. Angus Smith, read at a meeting of this Society on the 26th of January, 1881, it was stated in effect that the ammonia from 1,000,000 tons of coal, if used in manure as ammonium sulphate, would add about £533,000 worth of foods to the produce of the land; while, if the ammonia from all the raw coal now burnt in this country was utilized in agriculture, we should add £50,000,000 worth of bread stuffs, and might begin to export. Without venturing to say that this could be realized, I think it will be agreed that an increased supply of ammonia must be of immense importance to the agricultural prospects of this country.

The great value of ammonia renders it imperative that the greatest possible production should be obtained. It is usual to say that coal contains so much ammonia, but it is of course well known among chemists that such a statement is untrue, only the elements for its production being contained. These are nitrogen and hydrogen, and as the latter gas is always present in much greater quantity than is needed for the conversion of all the nitrogen into ammonia, it is the amount of nitrogen present that should determine the ammonia producing power of any coal. Unfortunately, only a small proportion of the nitrogen is thus made use of, about 40 per cent. remaining in the coke unchanged, while a large percentage is driven off with the gas in its elementary condition, and only from 14 to 20 per cent. combines with hydrogen to form ammonia. There is, therefore, much scope for ingenuity in finding some means for further utilizing the supply of nitrogen, and it is to be hoped that the researches of Professor W. Forster, M.A., some of which were embodied in a paper read before the Chemical Society of London, on the 21st of last December, will throw greater light on this important subject.

The composition of the gas collected from the Jameson ovens, after its passage through the condenser, varies according to the coal under treatment, and the length of time the charge has been burning. An approximate average is given in the following table:

CO_2	3·5
CO	27·5
H	29·3
O	1·1
N	38·6
	100·0

And from this it will be seen that, compared with London coal gas of average quality, its calorific power is about one-third. As a heating agent, therefore, assuming its cost to be 6d. a thousand cubic feet, the price for a given effect will be 1s. 6d., as against, say, 3s. for ordinary coal gas.

It cannot be overlooked that there is a very widespread feeling that the time is not far distant when the existing method of obtaining motive power by the generation of steam will be superseded by a more economical process, in which heat energy will be directly converted into mechanical work, without the intervention of a fluid such as steam, which, in the best compound engines, only permits a utilization of about one-tenth of the energy developed in the furnace. Expression was given to this by Sir Frederick Bramwell, F.R.S., at a meeting of the British Association in 1880, when he stated that if the Mechanical Section of that association should meet fifty years hence, he thought members would not speak of the steam-engine except as a curiosity to be found in museums. At the present time, gas engines of comparatively small power, constructed by Crossley Brothers, Limited, and using Dowson's gas, are actually working with a fuel expenditure of 1·4 lb. per indicated horse-power per hour, a performance rather better than that of the best steam engines; and though there are, doubtless, many practical difficulties to be overcome, I certainly look forward to the time when our present wasteful method of using coal, for obtaining motive power, will give way to a system more in accordance with the spirit of the age.

With these considerations in view, I think it is certain that the gas recovered in the coking process, instead of being consumed under a boiler, will be utilized in gas engines, for the production of all power required in the neighborhood of the ovens, for the working of the colliery and other machinery, and in adjacent factories; while there is also the probability of its use for the generation of power in the form of electric energy, to be transmitted for conversion into light or mechanical work. In this latter case, I of course refer to the establishment of large generating centers in the immediate neighborhood where the gas is produced, and in this connection the recent experiments of Deprez and Herz are especially interesting, and may possibly give the proposed application still greater importance.

It now only remains for me to ask your attention for a short time, while I make an appeal in favor of the substitution of gas and coke for heating purposes, both in manufactories and dwelling-houses, where raw coal is now employed. Look at it how we may, the use of raw fuel at the present time is only to be regarded as a relic of former ignorance, handed down for a time when the chemical compositions of coal and its products were unknown, when there was no use for ammonia, or for what we now call the by-products, and when economy was the last thing thought of, provided the desired result was obtained. Now, however, all this is changed. We have ascertained the composition of coal and its products with the greatest accuracy, and we know, as an absolute fact, that in burning the condensable volatile constituents we are consuming materials which, if applied in the arts and manufactures, have an intrinsic value many times above what they bear as heating agents. Besides which, we are producing smoke and dirt, fouling the atmosphere, and encouraging certain forms of disease, and in domestic fire-places, according to a favorable estimate, are sending 60 per cent. of the heat up our chimneys. And what is the set-off against all this? Nothing at all, as far as I can see, in regard to manufactories, where it is admitted gas would be a cheaper, more convenient, more easily regulated, and more cleanly fuel; while, in domestic fire-places, the luxury of having a blazing fire which can be poked is the only reason I have heard alleged in favor of the retention of the present system, which involves more expense and more labor than if gaseous fuel or coke had to be dealt with. I am not now alluding to the use of ordinary illuminating gas, which Sir Wm. Siemens has shown can be economically and advantageously applied as fuel in combination with coke; but I refer to a gas made specially with a view to heating purposes, such as the gas obtained in the Jameson process, and which would be supplied at a cost of not more than 6d. a 1,000 cubic feet. Such a gas would be available for all manufacturing purposes, and by using it with some regenerative system, the highest economy would be attained. It would also be delivered to our houses, and consumed for cooking and warming, either with or without coke, while it would also be suitable for driving gas motors, if indeed electricity, generated by engines worked with the gas near its point of production, had not previously stepped in for driving our domestic machinery. It is, however, difficult to see how electricity could compete with gas as an economical motor, unless it was on the score of simplicity, as with gas at hand, except under special conditions, it would obviously be cheaper to use it directly in an engine than through the medium of electric energy.

An interesting paper by Mr. George E. Davis is published in the February number of the *Journal of Chemical Industry* from which much practical information can be obtained as to the comparative values of various methods of warming rooms. The results arrived at, after many carefully conducted experiments, were that one ton of dry coke, burnt alone in a suitable stove, has the same heating effect as a ton of Lancashire coal, and is smokeless, and that twelve cubic feet of ordinary coal gas is about equal in heating effect to one pound of coal. In the following tables are given summary of costs for coal, coke, and gas, the latter being of the usual quality supplied in Manchester and rather better than what we have in London:

		Pence.
In fire-grate...	Coal, 40 lb., at 8d. a cwt.	2·86
	Coke, 50 lb., at 7s. 6d. a ton	2·00
Gas-stoves	Fletcher's, 240 c. ft., at 3s. per 1,000	8·64
	Lux Calor, 200 c. ft., " "	7·20
Stove.....	Coal, 18 lb., at 8d. per cwt.	1·20
	Coke, 20 lb., at 7s. 6d. a ton.	0·80

In a stove in use in Mr. Davis' study the cost per day is—

Coke for 13 hours, 14 lb., at 7s. 6d. a ton	0·56
Gas for lighting, 10 c. ft., at 3s. per 1,000	0·37
Total	0·92

and the temperature of the room is raised from 45° F. to 60° F. in one hour, and easily maintained. It would, therefore, seem that as a heating agent, coke is by far the most economical, especially when applied in a close stove. Unfortunately, however, this mode of application is one which is open to objection from several points of view. It first of all is incompatible with the generally accepted idea that the fire must be visible, and then there is the chance that, through some negligence, carbonic oxide may be permitted to escape into the room. I am, therefore, inclined to think that we should look to the heating of our dwelling-houses by the combustion of coke, with or without gas, in an open fire-place, specially constructed to carry on the operation in an economical way, but for convenience in lighting the coke, and in regulating the temperature, as well as from the more pleasant appearance of the fire, it appears probable that the combination of coke and gas, as suggested by Sir W. Siemens, will be the method more generally adopted.

At the present time, it is estimated that about 80,000,000 tons of coal are annually consumed in the raw state in this country. Probably part of this coal is unfit for coking; but even taking 60,000,000 tons as the quantity which might be treated by the Jameson process, we have, at present prices, £17,250,000 as the annual value of the by-products now being wasted, provided the gas could be utilized in the manner previously mentioned. This is exclusive of the sum of £5,750,000, previously referred to as the value of products which might be recovered from coke ovens now in operation, which would bring the total to no less than £23,000,000 a year. Besides this, it is possible to bring into use large quantities of duff and shale now left at the pits, from which both oil, ammonia, and gas could be extracted. The attainment of such a result is of immense importance, but it can only be accomplished along with the introduction of improved systems of obtaining motive power and heat, and surely these are matters well worthy the serious consideration of the members of this Society.

I will not now detain you further, but will conclude, in in the hope that what I have had the honor to lay before you this evening has been sufficient to establish the following propositions, which I had in my mind when I commenced:

1st. That Mr. Jameson's process meets a great industrial want that has hithero not been met.

2d. That it is desirable to do away with the use of raw coal as a fuel, substituting for it coke and gas, after the separation and recovery of the more volatile constituents.

MARIANINI'S RE-ELECTROMETER,

AND ITS USE IN THE STUDY OF ATMOSPHERIC ELECTRICITY.

In his lecture upon lightning rods, some time ago, Mr. Melsens mentioned the use of Marianini's re-electrometer for the study of atmospheric currents. This apparatus, which is a very old one, is not generally found described in

FIG. 1.—MARIANINI'S RE ELECTROMETER.

treatises on physics, and, as the mention of it in Mr. Melsens's note has brought us some inquiries in regard to it on the part of our subscribers, we have thought we could not answer them better than by devoting a few lines to the apparatus in this place.

The instrument was invented by Mr. Marianini in 1833 in order to serve as a galvanometer in some researches on the currents produced by piles. He had had the idea, in order to measure the intensity of currents, of availing himself of the magnetization that they produced in iron, and of measuring such magnetization by the deviations brought about in a magnetic needle by the polarity acquired by the metal.

His first apparatus consisted of a soft iron cylinder, 2 millimeters in diameter and 7 centimeters in length, covered with silk, and upon which was wound a silvered copper wire helix, one-fifth of a millimeter in diameter, and likewise covered with silk. The electro-magnet thus formed was placed above the center of an ordinary compass. The axis of the iron cylinder was at right angles with the magnetic needle, and the centers of this latter and of the electro-magnet, placed in the same vertical, were about 15 millimeters distant from one another. When a passage of a current into the helix had magnetized the iron of the cylinder, the needle deviated to the left or the right, according to the direction of the current, and such deviation was taken as the measure of the current's intensity.

After having used this apparatus with continuous currents, Marianini discovered that it was perfectly adapted for the study of instantaneous ones, such as those that are produced in the discharge of a condenser. In fact, upon discharging a Leyden jar through the helix, the iron was magnetized, and a deviation of the needle was obtained. But, as the iron preserved a certain amount of remanent magnetism, it became necessary, after each experiment, to bring it back to a neutral state through weak contrary discharges. In order to permit of this operation being performed by heat, or, if need be, to replace the iron bar, Marianini, instead of winding the wire directly upon the bar, wound it upon a glass tube into which there could be placed different bars when desired. Besides this, in order to vary the sensitiveness of the instrument, he furnished the helix with a movable support, by means of which it could be placed at different distances from the needle.

The apparatus thus modified is shown in Fig. 1, from the type which was exhibited in the Italian section of the Exhibition of 1881. The compass was, as may be seen, supported by three leveling screws, and its cardboard dial was capable, by means of an external appendage passing through a groove, of being moved within certain limits, so that its zero might be made to coincide perfectly with the position of the needle. From the edge of the box rose a vertical rod upon which ran one or more slides that carried grooved holders, L, upon which could be placed one or more helices, S, containing iron bars, F.

Another type, which was designed for the most delicate researches, had its needle suspended from the thread of a cocoon. Its general aspect was that of a Nobili galvanometer with very high supports. The rod carrying the slide was below the compass, and the helix was beneath the dial.

With this apparatus Marianini made a certain number of interesting researches.* He discovered, in the first place, certain analogies between instantaneous electric currents and voltaic ones, and then he demonstrated, in 1837, the induction produced by instantaneous currents, and which he named "leyd-electrique."

In 1840 he ascertained the curious fact that a bar of iron magnetized several times in one direction by instantaneous discharges, and then brought back to a neutral state by reverse discharges, acquires a greater aptness for being magnetized in this same direction, and a less one for undergoing a contrary magnetization. In 1843 he made known the use of the re-electrometer "as a means of discovering the direction of lightning."

"I have," said he, "demonstrated that, by means of the re-electrometer, we may turn aside from an excellent metallic conductor a portion of the ordinary electric current that is traversing it. I believe that we might be able to obtain the same result by acting upon the atmospheric electricity of lightning. To this end, I would propose to put in communication, by means of two long wires, the two extremities of the helix of the re-electrometer with two not too close points of an ordinary lightning-rod. I would place in the glass tube of the re-electrometer a bundle of iron wires, and, underneath, a compass so arranged that the axis should make a right angle with the magnetized needle, and that the middle of this axis and the center of the needle should be in the same vertical. Thus, every time that the lightning traversed the rod, a small portion of the electricity would circulate around iron wires, and the deviation of the needle placed beneath would indicate the deviation in magnetization, that is to say, would make known whether the lightning had ascended or descended the rod.

"Such an indication would be surer than that deduced from the electric state of the atmosphere before the appearance of the lightning, for it often happens in storms that the electric state of the atmosphere passes rapidly from positive to negative, and *vice versa*. However it is not stated

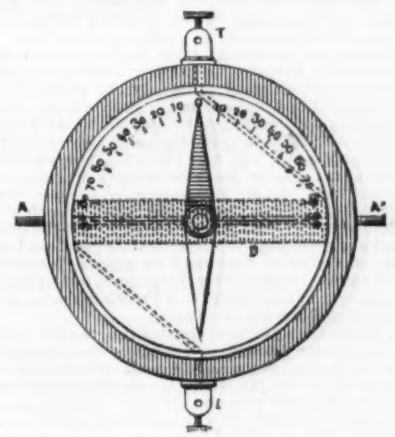


FIG. 2.—MELSEN'S MODIFICATION OF THE APPARATUS.

that from such an electric state of the atmosphere we can with certainty deduce that of the storm-cloud. Besides, the indication given by my instrument would have the advantage that it could be observed without haste, since the magnetization produced by instantaneous currents does not disappear, at least in great part, with the same rapidity as that derived from voltaic currents.

"Although the fraction of electricity turned aside from the conductor might be rendered as small as desired, and that too by having very near each other on the lightning rod the two starting points of the wires that communicate with the helix, yet there might be reason to fear that such small fraction would melt the wire that it was traversing.

"In order to overcome this difficulty, the instrument might be used in another way, that is to say, the two extremities of the re-electometer helix might be made to communicate by means of a wire, so as to constitute a closed circuit—about a meter of this wire being in a direction parallel with the lightning-rod, and a few meters distant from it. I am convinced, from my own experiments on the spark of the electric machine, that the re-electrometer would show the passage of the lightning in the rod; and, in this case, the instrument being electrified by induction, its indications would evidently be in a direction contrary to those that it would have given had the wire been traversed by a portion of direct electricity. It is very true, as we have seen, that when instantaneous currents act through induction, they produce a magnetization, now in one direction and now in another; but I have already remarked, in preceding memoirs, that when the tension is great the induced current has always the same direction, and that if the iron is entirely devoid of magnetization it will always become magnetized in the same direction.

"It is possible that, by this method, and only in increasing the length of that part of the wire that is parallel with the lightning-rod, the re-electrometer may be able to signalize the striking of lightning at notable distances; for, if a small Leyden jar gives us inductions at a distance of 80 centimeters, may we not conclude therefrom that lightning will give them at a distance of several meters? I would even dare hope that magnetization through induction might be obtained when the lightning was merely playing between the clouds, since leyd-electric inductions occur even when

* See *Annales de Chimie et de Physique*, 3d series, vol. x., p. 491; vol. xiii., p. 245; and vol. xvi., pp. 430 and 446.

the inducing conductor is nothing else than a stratum of air."

It is this mode of observation as pointed out by Marianini that Mr. Melsens has taken up. He has in the first place given the re-electrometer a simpler and more manageable form (Fig. 2). His apparatus consists of a round ebonite box, about 8 centimeters in diameter by 4 in height. At the bottom of this there is a helix, B, whose wire ends in two terminals, L and T, and whose internal tube opens in the sides of the box. Above the bobbin is the dial and magnetized needle. The apparatus is generally carried by a brass square upon which it is capable of revolving around the needle's axis of suspension, and which permits of its being easily fixed against a wall or other vertical support. For the iron wire there is substituted a steel one which is entirely devoid of magnetism. This substitution presents the advantage that the wire preserves all its magnetization, while, with the iron formerly employed, there was only a feeble residual magnetization.

It is under such a form that Mr. Melsens recommends the use of the re-electrometer for ascertaining the direction of the electric flux that is traversing lightning rods. In this case, one of the terminals, L, is put in connection with the rod, and the other, T, with the earth. The direction of the deviations obtained permits of determining, says Mr. Melsens, cases in which the earth thunderstrikes the heavens, and those in which the clouds thunderstrike terrestrial objects.

The apparatus is likewise applicable to observations upon telegraph or telephone lines, when put in connection, under proper conditions, with the ground wires of offices. It will be understood that a continuous observation of this apparatus permits of solving a certain number of questions connected with the electric phenomena of the atmosphere; and the direction of telegraphs of Belgium, as long ago as 1875, prescribed its use for the purpose of indicating, during storms, whether an atmospheric discharge traversed the wires running to the office, and of making known the direction of the discharge. Some interesting facts have already been observed; for instance, during a storm that lasted a couple of hours, the needle was seen, on continuously observing the re-electrometer, to pass several times from east to west, and *vice versa*, thus indicating frequent changes of direction in the discharges. It is allowable, then, to believe that the apparatus will be able to render services in what is now the order of the day—the study of atmospheric electricity.—*La Lumière Electrique.*

LAVOISIER AND CHEMISTRY.

IT has been a time-honored custom among English historians of chemical discoveries and theories to treat the great French chemist Lavoisier with some show of resentment, as having been guilty of some scientific thefts unworthy his great and deserved reputation; and Americans chose the centennial of Dr. Priestley's discovery of oxygen as a fitting occasion to celebrate what they were pleased to call the centennial of the birth of modern chemistry, though Dr. Priestley died stoutly denying the underlying principles of chemical philosophy, for which all chemists are indebted to Lavoisier, and to him almost entirely. The claim has been made by the admirers of Dr. Priestley that he discovered oxygen, that Lavoisier appropriated the discovery as his own, and found in it the key whereby he unlocked the previously insoluble mystery of combustion, the composition of the air, the constitution of salts, and the permanence of matter. On the other hand, French writers have admired in Lavoisier an experimentalist of the greatest skill and a philosopher of unexcelled and profound sense. M. Wurz succeeded in disturbing the general peace which prevailed among chemists over this dispute, some years ago, by saying that: "Chemistry is a French science. It was founded by the immortal Lavoisier."

Prof. Rodwell has further agitated this matter very recently, in a paper devoted to defending the character of Lavoisier as a man, and reasserting his pre-eminence as a thinker and a student. The paper is exceedingly interesting, and its contents will prove to be very useful and suggestive reading to those who have hitherto failed to gauge the intellectual superiority of Lavoisier. As far as possible in a limited abstract, we will summarize his positions and statements. Prof. Rodwell complains that historians of chemistry have showed themselves ignorant of facts in Lavoisier's work, that they have failed to give him credit for his constant and generous mention of contemporaneous investigators, that they use the term discoverer in too limited a sense, that there is reason to believe that Lavoisier was an independent if not original discoverer of oxygen, that they do not sufficiently emphasize, or portray the revolution of ideas caused by Lavoisier's protest against the old theories. The inquiry into this subject has been greatly assisted by the publication by the French Government of Lavoisier's complete works, which have never before been gathered and issued in such a convenient form. Lavoisier's first memoir was published in 1768, from which time up to 1790 he communicated fifty-eight papers to the scientific world embodying the views he promulgated in his new chemical philosophy. Besides these special studies he published thirteen reports upon different subjects relative to practical applications of science, a volume upon a new chemical nomenclature, and two volumes entitled "A Treatise of Chemistry."

With the assistance of these publications Prof. Rodwell has prepared his elaborate and descriptive paper upon Lavoisier and modern science.

In the first place many authorities place Lavoisier's discovery of the composition of air in the year 1789, when as a matter of fact the principles contained in his treatise of that date had appeared twelve years before under his name, and Lavoisier had obtained oxygen from mercuric oxide 14½ years before. Again, Dr. Thomas says, speaking of the *opuscules* of Lavoisier, that nothing in them indicate Lavoisier's apprehension of the exact nature of air, and the part its oxygen plays in the phenomena of combustion. Nothing could be more erroneous. The *opuscules* bear the date of the 3d of December, 1773, and they contained the results of ten years' previous investigation. They established in the clearest manner that the atmosphere is a compound of two bodies, of which one is consumed in the process of combustion. Scheele had not at that time reached any such conclusion; it preceded by eight months Priestley's discovery of oxygen by heating mercuric oxide, and by more than a year his apprehension of its exact nature. Again, it is constantly reiterated that Lavoisier took his suggestions from other writers, and neglected allowing them any credit. On the contrary, his papers abound in evidence of his regard for other investigators, and again and again as quoted by Prof. Rodwell he speaks of Dr. Priestley in the most admired manner, admitting his indebtedness to him for whole series of experiments, but insisting with courteous firmness upon a different or better presentation of the principles they establish. Finally, in regard to the repeated accusation of his unjust claim to the discovery of oxygen, his apologist urges this defence: In Lavoisier's "Treatise on Chemistry," 1789, he says. "This gas that Mr. Priestley, Mr. Scheele, and I have discovered at about the same time has been named by the former dephlogisticated air; by the second, air empyreal; I have given it the name of *air eminently respirable*, and since then have replaced that designation with that of *vital* air. Now it is well known that Scheele did not make the gas until 1775, and it is urged by Rodwell that Lavoisier speaks here in a general manner. But in another memoir Lavoisier, speaking of oxygen, says: "This gas, which Mr. Priestley discovered almost at the same time as myself, and indeed, I think, *before me*." Granting the mere priority in time of Priestley's discovery, Prof. Rodwell seems to think that Lavoisier may have made an independent though subsequent acquaintance with it. However that may be, and in reality there is good reason to assign to Priestley alone the discovery of oxygen, though Lavoisier may have ventured some surmises upon the possible preparation from mercuric oxide of a similar gas, it is true that Dr. Priestley remained in complete ignorance of its properties until March, 1775, and that Lavoisier long before that recognized its qualities as clearly as we know them to-day. To Lavoisier Prof. Rodwell assigns the honor of its *virtual* discovery, as without him the experiments of Scheele and Priestley would have had but a slight effect upon contemporaneous chemical science, whereas with him the foundation of modern chemistry was imperishably established.—*L. P. G.*

CONTAGIOUS CONSUMPTION.

JUST before his death, which took place about six weeks ago, Dr. Krishaber was awarded the prize Montyon of 2,500 francs by the Academy of Sciences, which he shared with Dr. Dieulafoy for their conjoint work on the inoculability of tuberculosis. This they have sufficiently demonstrated by a series of experiments upon monkeys, of which Dr. Krishaber had a large collection. Of fourteen monkeys that were inoculated, twelve died tuberculous in from 34 to 218 days, in spite of the favorable hygienic conditions in which they were placed. The contagiousness, or rather the infectious nature, of the affection in the form of pulmonary phthisis was not the less proved, as may be seen by the following examples:

A small, dog-faced monkey, which had been living at liberty in the house of one of the experimenters, was put into the menagerie among other monkeys which had been inoculated. One of the old inmates got attached to the newcomer, which was constantly between its arms, and both died at an interval of nine days of each other, the internal organs having been found to be attacked by tuberculosis. Subsequently the menagerie in which the experiments were performed was cleaned out and thoroughly disinfected. Twenty-seven monkeys were then put into it, and since that time—that is, during fifteen months—there was not a single death from tuberculosis. These experiments were considered sufficient to prove that pulmonary phthisis was transmissible by inoculation and by cohabitation.

Dr. Villemin, principal physician and professor of clinical medicine at Val-de Grace, has generally been considered the real discoverer of the inoculability and contagiousness of tuberculosis, which he proved experimentally nearly twenty years ago. It appears, however, that the Germans have since published several works on the same subject, which, with slight modifications, are the exact reproduction of Dr. Villemin's memoir, published in 1865, but without any acknowledgment of the original source. Such an act of piracy could not be tolerated by the French, and a large number of professors and other medical men of the Faculty got up a banquet, with the view of publicly expressing their indignation and rendering justice to Dr. Villemin.—*Lancet Correspondence.*

DISEASES OF THE TONGUE.

As I have just hinted, the conditions which favor the development of fur on the tongue are briefly those of rest. If we can fully realize this fact, it will help us to the explanation in a very simple manner of most of the morbid conditions of the tongue met with in acute diseases. When the tongue is quiet, the papillæ grow freely, their hairs accumulate epithelium, and on the epithelium colonies of micrococci flourish. Large allowance must be made for individual peculiarity, for it is only in those in whom the filiform papillæ are abundant and large that any development of fur can take place. It is well known that most persons have more or less coated tongues before breakfast, and that the taking of a meal rubs off the fur and cleans the tongue. It is also well known that when the tongue cleans it usually does so from its end and sides; leaving the middle of the dorsum and especially the posterior part still covered. The explanation of this is easy, for the parts which clean first are precisely those which are most rubbed against the teeth and hard palate.

It is very common to see tongues which do not clean in the manner just described, but in which one longitudinal half of the tongue is clean while the rest is furred. In these cases the line is never abrupt in the middle, but it is usually to be noticed that considerably more than half is clean and less than half, or, it may be, a mere streak on one side remains furred. The explanation of this condition is, I believe, always to be found in the fact that the patients in whom it is observed eat chiefly or only on one side of the mouth.

It does not matter in the least what the cause of the one-sided mastication may be, whether there is a tenderness or the absence of teeth, the result is just the same. If a patient eats on one side only of his mouth, he rubs that side of his tongue much cleaner than the other. I am, of course, aware that one of my distinguished predecessors in this chair, the late Mr. Hilton, an observer and reasoner from whom I would differ with great diffidence and reluctance, propounded another theory, and that his suggestion has been widely accepted.

Mr. Hilton's observations of the facts were exactly the same as my own, at any rate thus far, that he noticed that those who had aching or tender teeth got the tongue furred on the side of the bad tooth. His explanation was that the fur was produced in a reflex manner through the influence of the fifth nerve, and was an instance of disturbance of function and nutrition by nerves.

Apart from the consideration that it is desirable to avoid calling to our aid nervous disturbances concerning which we can prove nothing, when they are not required, I must contend that the simple mechanical explanation which I have given covers the whole ground, and accounts for a large number of cases which the other would fail to explain. It is certainly not the fact that painful teeth are present in all cases of unilateral furring of the tongue. In many, I think in the majority, the condition is rather the absence of teeth.

The condition of accumulation of white or dirty-brown fur in the back part of the mid-dorsal region is exceedingly common. It is to be explained in the same manner that we have suggested in the case of the unusual growth of the filiform papillæ in this region, being, indeed, to some extent the same thing. This is the part of the tongue the best protected from pressure and friction, and upon which both papillary and fungoid growth takes place, therefore, most easily. When fur collects in patches in local regions elsewhere than in the middle, some local peculiarity in the mouth is to be suspected. There may be a sore on the palate, making it painful to apply the tongue to that part, or there may be an aching tooth, or a gap in the row of teeth, or a sharply broken stump. Any of these conditions may favor the occurrence of patches of fur, but such patches are seldom well defined or very conspicuous.

Absence of fur—a simply clean tongue—is indicative, usually, of a good appetite and free mastication in all parts of the mouth. It generally implies, in addition, that the development of the filiform papillæ is only moderate. On the other hand an habitually foul tongue, without dyspepsia or ill health, usually indicates an excessive growth of these papillæ and their appended processes.—*Jonathan Hutchinson, F.R.C.S., Medical Press.*

THE PERAK TIN MINES.*

THIS interesting memoir, which forms part of the *Archives des Missions scientifiques et littéraires*, série iii., vol. ix., gives the result of a seven months' exploration of the Malay State of Perak, made by the author, who was sent by the French Government upon a mission of scientific inquiry into the Malay Archipelago in 1881. Perak, although an insignificant unit among even the smallest States of the world, its extreme dimensions being only 95 by 50 miles, or an area of less than 5,000 square miles, has long been known as a tin producing country, being mentioned in the narratives of Tavernier, and the Dutch and Portuguese navigators of the seventeenth century; but it is only since the large influx of Chinese miners, consequent upon the suppression of the Taeping rebellion, that it has become of first-rate importance. The success attained by the first comers led to a rapid increase of the Chinese population, who arrived in such numbers as to be soon beyond the control of the feeble Malay Government, and the mining being carried on without any regulations as to boundaries, the miners became divided into two parties, who made war upon each other with varying success, the Sultan looking on impartially during the contest, but siding with the winners. The defeated party in 1872, having taken to piracy at sea, was suppressed by English gunboats, and a resident was appointed for the purpose of keeping order; but the Malays having revolted in 1875, when the resident was murdered, the country has since been placed under a British protectorate, with a native rajah, under the title of Regent. This has been attended with the happiest results, the country having made great progress during the last six years, under the vigorous and enlightened management of the resident, Hugh Low, Esq., C.M.G., and now bids fair, according to the author, to become the most considerable producer of tin in the world.

The mines worked up to the present are entirely alluvial or stream works, the water courses being filled with sand and gravel deposits to a depth of 20 or 30 feet, resting upon a floor of pure china clay, apparently derived from the decomposition of the granitic rocks forming the numerous parallel ridges which traverse the country from north to south. The geological description is necessarily imperfect, owing to the dense tropical vegetation which covers the entire country; but the author has been able to establish the presence of numerous quartz veins traversing the granites, which are coarsely porphyritic in the center, and largely charged with tourmaline at the edges of the masses, in fact reproducing the phenomena observed in the northwestern tin districts of Cornwall. No mines have as yet been opened in any of these veins, but the author speaks of blocks of tin ore weighing more than 1 cwt. as having been found in the immediate vicinity of the hills, which are evidently not far removed from their original position. The bulk of the production is, however, derived from smaller rounded crystalline masses and grains contained in the lower part of the alluvial gravel, the workable thickness ranging from 7 to 10 feet, and the proportion of clean ore or "black tin" from about 1 to 4½ per cent. by weight. This is remarkable for its purity, being almost entirely free from wolfram, arsenic, and other foreign substances, which are so troublesome to the Cornish tin miner. The methods of working, mechanical preparations, and smelting of the ore are of the simplest possible kind, the work, with the exception of a few centrifugal steam pumps, and of Chinese chain pumps driven by water wheels, being entirely carried out by manual labor, with furnaces and other appliances of the most primitive types. This simplicity adds considerably to the interest of the author's detailed and carefully illustrated description, which enables the reader to realize in imagination the conditions prevailing in our western districts in the days when the Phœnicians traded with the Cornish miners for tin at St. Michael's Mount. Under the new British rule, the country has made rapid progress, the output of tin having risen from 2,059 tons in 1879 to 5,994 tons in 1881, the whole of which is exported through Penang. As at the latter date the cost of production, including revenue charges of about 17 *l.*, was estimated at about 61 *l.* per ton, while the local selling price was 88 *l.*, showing a profit of 45 per cent., the popularity of the business is sufficiently explained. It is not probable, however, that such large profits will continue to be realized after the more productive deposits have been exhausted. It does not appear from the narrative that European labor of any kind is employed, the workpeople belonging to three races, namely, Malay aborigines, Klings or coolies from Madras and the Malabar coast, and Chinese, the latter supplying the whole of the miners, smelters, and other artisans directly employed in producing the metal. The author has a very high opinion of the Chinese miners, who are described as sober, regular in work, and accustomed to co-operative enterprises, against which, however, must be set the defects of being addicted to excess in opium and gambling, besides being very quarrelsome, and exceedingly superstitious. The latter failing is, however, of interest as reproducing the old European legends of guardian genii of the mine, the "Kobads" of Germany, and "Knockers" of Cornwall, who require to be propitiated by sacrifices and kept in good humor by orderly behavior on the part of the miners. Infractions of the last rules are punished by the

* "Les Mines d'Etain de Perak." Par J. Errington de la Croix. 8vo. Paris, 1881.—*Nature.*

withdrawal of the guardian gnome, who takes all the unwrought ore in the mine away with him. The execution of the work, both as regards illustration and typography, is exceedingly good, and reflects great credit upon the French National Printing Office.

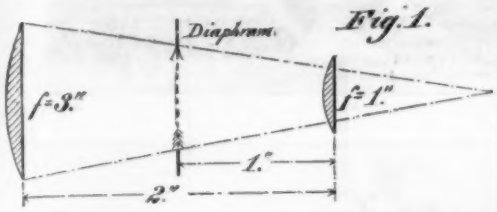
EYE PIECES FOR TELESCOPES AND MICROSCOPES.

By G. D. HISCOX.

To meet the many inquiries in regard to the forms and powers of eye pieces for telescopes and microscopes, we herein illustrate the various approved forms, and give the formulas for constructing, and also tables of powers sufficient for the wants of most amateurs.

The eye piece most in use for astronomical telescopes and microscopes is of the Huyghenian form; the principal components of which are plano-convex lenses, set with their plane sides next to the eye, the relative focal lengths for the best form being as three to one, and the distance from face to face of the plane sides being equal to one-half the sum of their focal lengths.

Fig. 1.



The expression for determining the focal length of an equivalent lens for the above form is $\frac{3'' \times 1'' \times 2}{3''+1''} = 1\frac{1}{2}'' =$ the focal length in inches of an equivalent lens. Ten being the assigned measure of the power of the eye in inches, then $\frac{10}{1\frac{1}{2}} = 6\frac{2}{3} =$ the power of the eye piece.

Then for the magnifying power of the telescope, divide the focal length of the object glass by the value of the equivalent lens of the eye piece. Thus, with an object glass of 50 inches focus, and the equivalent lens of 1½ inches, $\frac{50}{1\frac{1}{2}} = 33\frac{1}{3} =$ the magnifying power required.

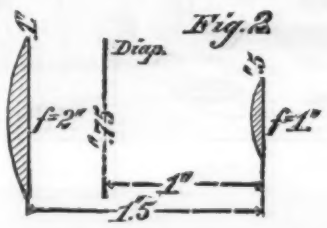
Again, if the *power* of the eye glass is used as a factor, the *power* of the object glass must also be used for the other factor. Then, as above, 10 being the measure of the eye, $\frac{10}{1\frac{1}{2}} = 5 =$ the power of the o. g., and $5 \times 6\frac{2}{3}$, as above, $= 33\frac{1}{3} =$ the magnifying power of the telescope.

In the following table are given the proportions, equivalents, and powers of a convenient range of eye pieces of this form:

Field lens.	Distance.	Eye lens.	Equivalent lens.	Power.
3·75"	2·5"	1·25"	1·88"	5·33
3	2·	1·	1·50	6·66
2·5	1·66	0·83	1·25	8·
2·	1·33	0·66	1·	10·
1·5	1·	0·50	0·75	13·3
1·	0·66	0·33	0·50	20·

The proportions of the above eye pieces are not strictly followed by makers; the variations being generally adopted for the purpose of obtaining a larger angular field, or for the convenience of using such lenses as are most available, of which Fig. 2 is an example of this modification, having an angular field of about 60°.

Fig. 2.



This variation has not been found to extend beyond a relative focal value of the components of two to one. Any relative proportions of the two lenses between 3 to 1 and 2 to 1 have their approximate equivalents expressed in the

RULE.

Multiply the focal length of the field lens by the focal length of the eye lens; divide the product by the distance between the lenses (which is half the sum of their focal lengths). The quotient is the focal length of the equivalent lens.

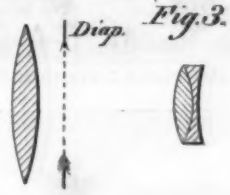
With this rule in view, eye pieces can be constructed with lenses of random focal lengths between the margins of Fig. 1 and Fig. 2.

The following table gives the proportions and values of the forms represented by Fig. 2 for several powers, and which also corresponds with the usual forms of microscopic eye pieces as made by some of the leading opticians:

Field lens.	Distance.	Eye lens.	Equivalent.	Power.
3·"	2·25"	1·50	2·	5·
2·50	1·875	1·25	1·666	6·
2	1·5	1·	1·333	7·5
1·50	1·125	0·75	1·	10·
1·	0·75	0·50	0·666	15·
0·75	0·5625	0·375	0·50	20·

A modification of the above type is the orthoscopic or Kelner eye piece, Fig. 3, in which the field lens is of crown glass, double convex, the eye lens being a slightly over-corrected achromatic pair, consisting of a double convex crown and a double concave flint cemented together with Canada balsam.

Fig. 3.

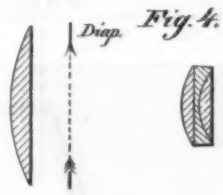


The proportions and powers of this eye piece are given in the above table.

Its claim for merit, as its name implies, is a more perfect correction of both aberrations.

Another modification of the Huyghenian form is called the periscopic eye piece; it has a plano-convex field lens, and a Lister triplet (a plano-convex triple achromatic combination) for the eye lens, cemented with Canada balsam. Fig. 4.

Fig. 4.



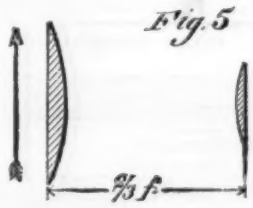
The eye lens, or Lister triplet, consisting of two plano-convex crown lenses, with a plano-concave flint lens between, cemented. This eye piece is mostly made for microscopes, and claims a more perfect definition over the entire field than the ordinary Huyghenian form.

The class of eye pieces having their focal planes beyond the field glass, or between the field glass and the object glass, are much used for specific objects, as a flat field for giving a clear view of the cross wires or webs in transits and micrometers, a large angular field for finders and comet seekers.

The first of this series is the negative eye piece, having for its components two plano-convex lenses, of equal focal lengths, set with their plane sides toward the object glass, and at a distance of three-quarters of the focal length of either lens. This is an early form, made for the purpose of obtaining achromatism with two crown glass lenses; but now become obsolete by the introduction of new formulas.

The Ramsden eye piece consists of two plano-convex lenses, of equal focal lengths, the eye lens being one-half the diameter of the field lens, and thinner in proportion; and placed at a distance from each other of two-thirds the focal length of either lens, with their plane sides outward, as in Fig. 5.

Fig. 5



The focal length of an equivalent lens is equal to three-fourths of the focal length of either lens. This form is not quite achromatic, or aplanatic, *i. e.*, free from both aberrations.

A modification of this original form, now in general use, gives a much larger field, and is a favorite for comet seekers.

It consists of two plano-convex lenses, their local lengths being in the proportion of three to one; their diameters also three to one, with their plane sides outward; distance from face to face equal to the positive local length of the eye lens (*i. e.*, when measured from the plane side), as shown in Fig. 6, which represents the full size and figured dimensions of an eye piece equivalent to a three quarter inch lens.

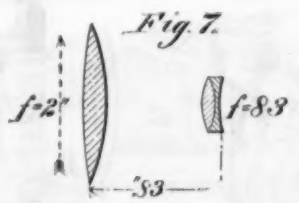
Fig. 6.

This form is nearly achromatic, and has an angular field of 90°.

Eye pieces of this form may be made of various powers by proportionally changing the focal lengths, distance, and diameters, as given above.

An improvement upon this form, by Prof. Steinheil, designated as the achromatic Ramsden or Steinheil eye-piece, has the same general proportions as given in Fig. 6. The field lens is a double convex crown, curves two to one, flattest side toward the object glass. The eye lens is a slightly over-corrected achromatic pair, consisting of a double convex crown and a double concave flint lens, cemented with Canada balsam, as shown in Fig. 7.

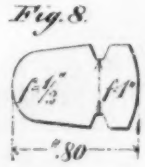
Fig. 7.



A more perfect achromatism, and freedom from spherical aberration, are claimed for this form than is due to the plain eye pieces, Figs. 5 and 6.

The solid eye-piece is much used for high powers, where the largest transmission of light is desirable; it is made of a single piece of glass, with focal curves, two to one; a groove being cut around the cylinder at the focal distance of the eye end, as shown in Fig. 8, which represents a half-inch equivalent, full size.

Fig. 8.



The solar eye piece is really not an eye piece in itself, but rather an attachment to an eye piece, for the purpose of absorbing or passing by the excessive light and heat from the full aperture of the object glass, or casting, as in Fig. 9, a faint image at right angles to the axis of the telescope. There are several kinds of solar eye pieces; the most approved form we illustrate in Fig. 9, as giving the definition due to the full opening of the object glass, and requiring but a slightly absorbing medium or colored glass at the end of the eye glass.

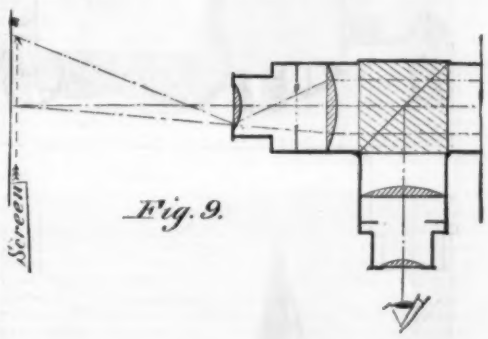


Fig. 9.

This form of solar eye piece is made with two right angled prisms with their diagonal faces cemented together with Canada balsam, the difference in density between the glass and the balsam giving a reflected image of about one twenty-fifth part of the direct image. Thus, the reflected image is used for ocular observation, while the transmitted image may be utilized upon a screen for multocular observation.

The terrestrial or erecting eye piece has been modified many times by different makers. It originally consisted of three lenses; but the most approved form, Fig. 10, now in use,

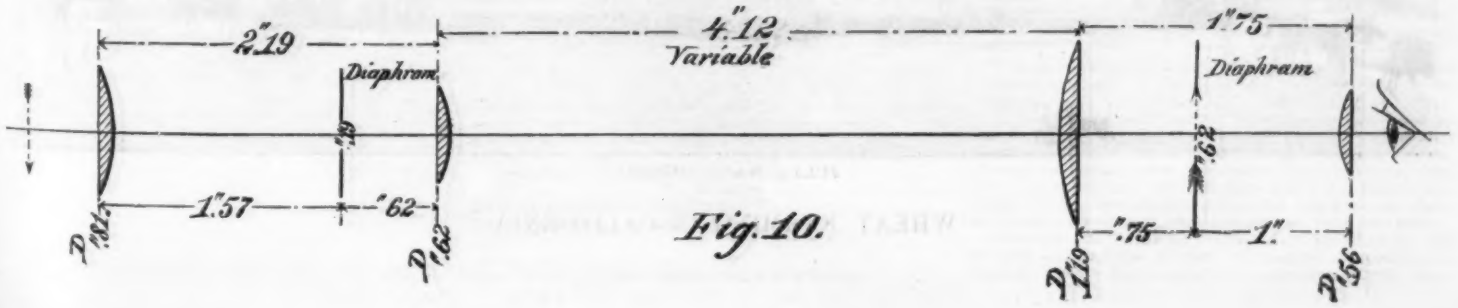
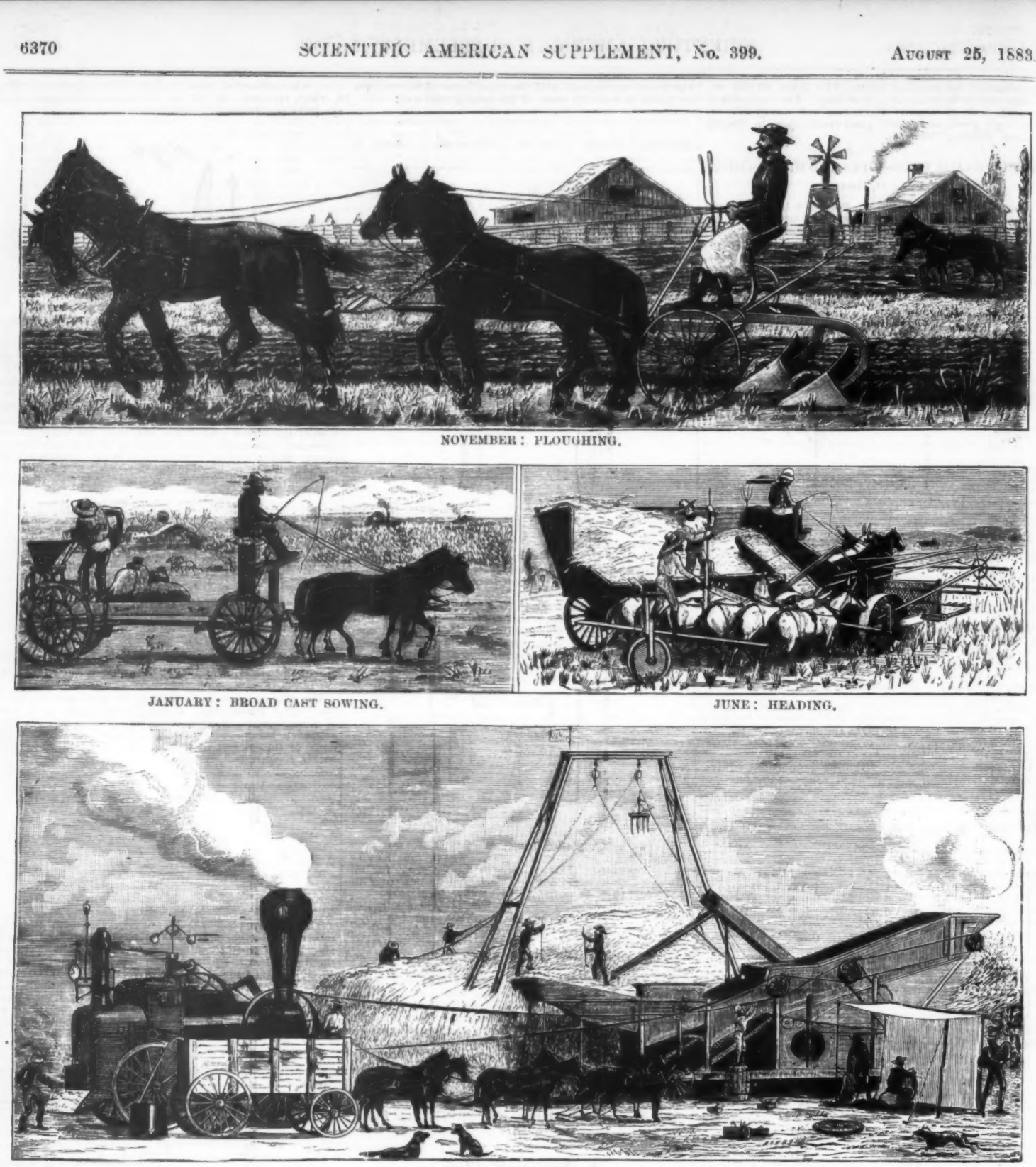


Fig. 10.

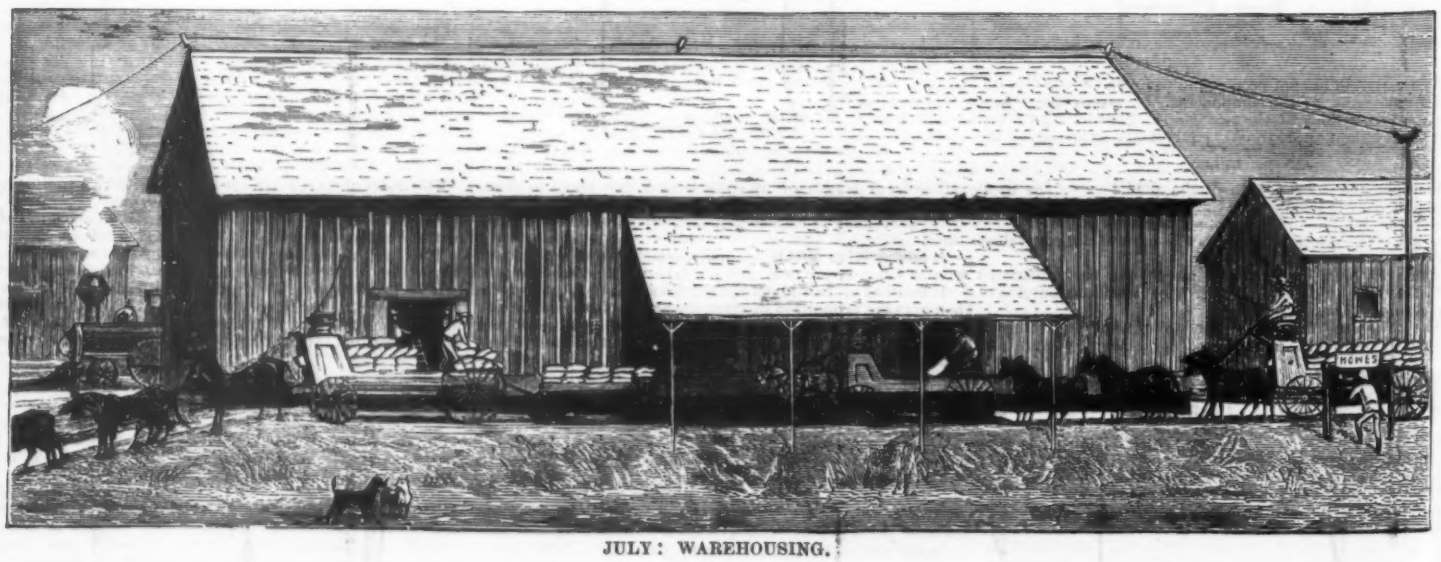
NOVEMBER: PLOUGHING.

JANUARY: BROAD CAST SOWING.

JUNE: HEADING.



JULY: THRESHING.



JULY: WAREHOUSING.

WHEAT FARMING IN CALIFORNIA.

is made with four lenses, all plano-convex; the pair of lenses next the eye being an exact counterpart of the modification of the Huyghenian eye piece as given in Fig. 3. The pair next the object glass having their plane sides towards the object glass, as illustrated in the figured cut, which gives the proportional parts in hundredths of an inch. This represents an eye piece of a power equivalent to a single lens of one inch focus, or a power of 10. This will give a magnifying power of 40 with a 40 inch object glass, and powers in proportion for other focal lengths.

Variations of this form for different powers may be made by changing the focal lengths, diameters, and distances apart of all the lenses, as nearly proportional as possible.

The pancratic form of this eye piece consists of an arrangement of the tubes made for the purpose of sliding the two end combinations nearer or further apart, whereby a small variation of the magnifying power may be obtained.

WHEAT FARMING IN CALIFORNIA.

THESE engravings are from sketches by Mr. H. W. Rawlins, of Hanford, Tulare Co., California. He writes thus concerning them:

No. 1.—Owing to the land being stoneless, and, as a rule, fenceless, we use different kinds of "gang plows," the most popular of which is the "sulky," which carries two plows, each cutting a furrow of twelve inches, and is regulated by three levers. The one in front regulates the "draught," so that the plow can be made to cut the full twenty-four inches, or any smaller amount required; that on the left regulates the depth of the plow's cut, while that on the right side of the driver is used for lifting the plows out of the ground while turning a corner or moving from one place to the other.

No. 2.—In a good year, when there is plenty of rain, a very favorite way of "seeding" is by means of a "broadcast sower," which is placed in the back end of a two-horse wagon, and worked by a chain running round a large cog-wheel fixed on the axle of the wagon. It sows a "land" of about thirty feet broad at a time, and is generally followed by one or more four-horse harrows, each of which cuts twelve feet.

No. 3.—As straw is not worth anything, we have a machine called a "header," which cuts the grain about eight inches below the ear. The "header" is pushed by six horses, and the grain is carried on a "draper" from behind the knives up into the "header wagon," from which it is stacked in the field ready for thrashing. From ten to thirty acres go to "form a stack," according to the yield of grain. Above the knives runs a "reel," which bends the straw over the draper before it is cut.

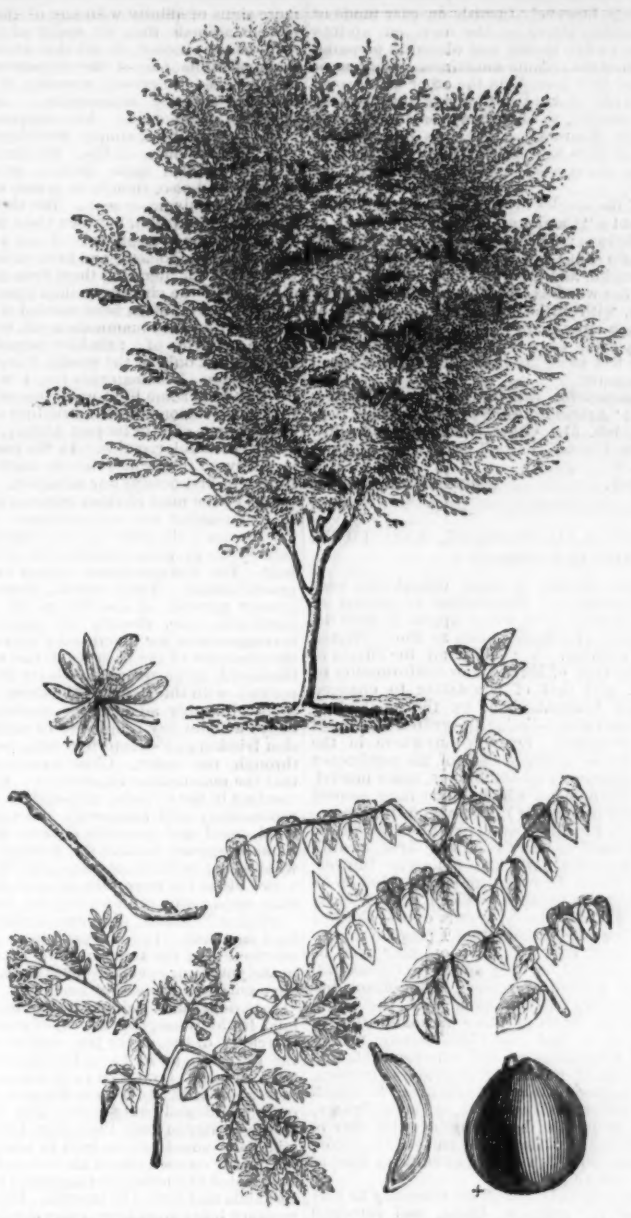
No. 4 shows the kind of engine and separator we have here. The engine is fed with straw by the fireman, whose sole duty it is to keep the furnace supplied. Alongside of the engine is the water wagon, which is used to keep on hand a good supply of water for the engine. Above the separator is the derrick, with two horse forks attached, which, being "set" in different parts of the stack by the "forkers," are hauled up by horses (which are on the other side of the separator) and "dumped" on the "table," where two "tablers" work all the time, shoving the straw into the "self-feeder." At the right end of the machine where the straw comes out is the "strawback" team, which keeps the straw hauled away from under the spout.

No. 5.—As a rule, directly the wheat is thrashed, it is hauled into the warehouses, and either stored for higher prices, or shipped through them to San Francisco. The warehouses are raised on piles, so that the floor is on a level with the bottom of the cars on the railroad, so that the grain can be wheeled straight from the wagons into the cars.—*London Graphic.*

[THE GARDEN.]

THE KENTUCKY COFFEE TREE.

THIS is a perfectly hardy, free-growing subject, quite dissimilar in general aspect from any other tree which flourishes in the open air in Great Britain—the large handsome, bluish green, twice pinnate leaves, which in young, vigorous specimens often measure as much as three feet in length by two feet across at the base, giving it a decidedly tropical appearance. It succeeds in almost all soils and positions, is one of the easiest trees to transplant, and supports drought well. On the dry, gravelly soil of the old arboretum at Kew there was a fine example of this tree, which, we learn from that recently published and very useful book of reference, Smith's "Dictionary of Popular Names of Economic Plants," was a hundred years old in 1864, and was besides of particular interest on account of its being one of a collection of trees presented by the then Duke of Argyle (Walpole's tree-monger) to George III. on the establishment of the gardens. The veteran ex-curator should, however, have used the past tense, as the tree died and was removed several years ago. Under widely different conditions we have seen the Kentucky coffee tree flourishing in a northern county in an exposed condition on a cold and retentive clay bank. Anything, in fact, short of absolute stagnation in the soil it seems to withstand readily enough, so the tree is one which should be freely planted for effect in parks and pleasure grounds. Under favorable circumstances it attains a height of sixty feet or more, the accompanying illustration being a representation of a full-grown specimen at Syon, which forty years ago measured fifty-seven feet in height, with a head forty-seven feet through and a trunk three feet in diameter.



YOUNG KENTUCKY COFFEE TREE (*Gymnocladus canadensis*), AND FLOWERS, FRUIT, AND FOLIAGE.

FULL-GROWN SPECIMEN OF KENTUCKY COFFEE TREE (*Gymnocladus canadensis*).

In Loudon's "Arboretum" a considerable number of measurements are given, and the following statistics are extracted from that work. It would be of great interest if readers of *The Garden* would forward to the editor the present sizes of these trees, so that their progress could be recorded for the interval which has elapsed since the publication of Loudon's famous work.

England.—In the environs of London, at Whitton, eighty-seven years planted and sixty feet high; at Kenwood, twenty-five years planted and twenty feet high; in Kent, at Cobham Hall, twenty-five years planted and twenty feet high; in Surrey, at St. Anne's Hill, thirty years planted and forty-five feet high; at Claremont, forty-five feet high, the diameter of the trunk eighteen inches, and of the head thirty-five feet; at Farnham Castle, forty-five years planted and twenty-five feet high, the diameter of the trunk twelve inches, in poor soil on chalk; in Oxfordshire, in the Oxford Botanic Garden, forty years planted and thirty-five feet high, the diameter of the trunk one foot two inches, and of the head fifteen feet; in Worcestershire, at Croome, forty years planted and sixty feet high, diameter of the trunk eighteen inches, and of the head thirty feet.

Scotland.—Edinburgh Botanic Gardens, fifteen feet high; Glasgow Botanic Garden, twelve years planted and thirteen feet high.

Ireland.—Glasnevin Botanic Gardens, twenty-four feet high, diameter of the trunk six inches, and of the head seven feet.

Continent.—Paris Jardin des Plantes, sixty years planted and fifty-five feet high, the diameter of the trunk twenty inches and of the head forty feet; Botanic Garden, Toulon, twenty years planted and twenty-five feet high; near Metz, sixty years planted and sixty-five feet high; Sans Souci, Berlin, thirty years planted and thirty feet high; in Italy, at Monza, twenty-nine years planted and forty feet high.

Although the Kentucky coffee tree produces in this country its terminal racemes of somewhat conspicuous whitish flowers freely enough, it probably rarely or never

fruits. Imported seeds, however, furnish an easy mode of propagation, and, besides, pieces of the roots cut up into lengths of four inches or five inches and placed in prepared beds kept moist develop into plants sometimes three feet or four feet in height the first year. On the other hand, some of the pieces may hardly start at all during that period, but still retain their vitality, so should not be disturbed or destroyed. The name Kentucky coffee was bestowed on the tree by the early settlers in Kentucky and Tennessee on account of their using the roasted seeds as a substitute for coffee.

The distribution of the species in a wild state is given in Professor C. S. Sargent's "Catalogue of the Forest Trees of North America," as follows: "From Western New York and the Province of Ontario south to Tennessee; west to Wisconsin, Eastern Nebraska, and the Indian Territory." The same work describes the wood as rose-colored, close-grained, compact, very tough, with little sap wood; susceptible of a high polish, although cross-grained and difficult to season and to work. Its specific gravity is 0·609. It attains a height of from sixty feet to eighty feet, with a trunk sometimes two feet in diameter.

Identification.—Gymnocladus canadensis.—Lam.: Encycl. Meth., i., 73. Michx.: "Arbres Forestiers de l'Amerique Septentrionale," ii., 241, tab. 51. Gray: "Manual of the Botany of the Northern United States," 145. Koch: "Dendrologie," theil 1, p. 5.

Royal Gardens, Kew. GEORGE NICHOLSON.

ON WHALES, PAST AND PRESENT, AND THEIR PROBABLE ORIGIN.*

FEW natural groups present so many remarkable, very obvious, and easily appreciated illustrations of several of the most important general laws which appear to have determined the structure of animal bodies as those selected for my lecture this evening. We shall find the effects of two opposing forces—that of heredity or conformation to ancestral characters, and that of adaptation to changed environment, whether brought about by the method of natural selection or otherwise—distinctly written in almost every part of their structure. Scarcely anywhere in the animal kingdom do we see so many cases of the persistence of rudimentary and apparently useless organs, those marvelous and suggestive phenomena which at one time seemed hopeless enigmas, causing despair to those who tried to unravel their meaning, looked upon as mere will-of-the-wisps, but now eagerly welcomed as beacons of true light, casting illuminating beams upon the dark and otherwise impenetrable paths through which the organism has traveled on its way to reach the goal of its present condition of existence.

It is chiefly to these rudimentary organs of the Cetacea and to what we may learn from them that I propose to call your attention. In each case the question may well be asked, granted that they are, as they appear to be, useless, or nearly so, to their present possessors, insignificant, imperfect, in fact *rudimentary*, as compared with the corresponding or homologous parts of other animals, are they survivals, remnants of a past condition, become useless owing to change of circumstances and environment, and undergoing the process of gradual degeneration, preparatory to their final removal from an organism to which they are only, in however small a degree, an incumbrance, or are they incipient structures, beginnings of what may in future become functional and important parts of the economy? These questions will call for an attempt at least at solution in each case as we proceed.

Before entering upon details, it will be necessary to give some general idea of the position, limits, and principal modifications of the group of animals from which the special illustrations will be drawn. The term "whale" is commonly but vaguely applied to all the larger and middle-sized Cetacea, and although such smaller species as the dolphins and porpoises are not usually spoken of as whales, they may to all intents and purposes of zoological science be included in the term, and will come within the range of the present subject. Taken altogether, the *Cetacea* constitute a perfectly distinct and natural order of mammals, characterized by their purely aquatic mode of life and external fishlike form. The body is fusiform, passing anteriorly into the head without any distinct constriction or neck, and posteriorly tapering off gradually toward the extremity of the tail, which is provided with a pair of lateral pointed expansions of skin supported by dense fibrous tissue, called "flukes," forming together a horizontally-placed triangular propelling organ. The forelimbs are reduced to the condition of flattened ovoid paddles, incased in a continuous integument, showing no external sign of division into arm, forearm, and hand, or of separate digits, and without any trace of nails. There are no vestiges of hind limbs visible externally. The general surface of the body is smooth and glistening, and devoid of hair. In nearly all species a compressed medial dorsal fin is present. The nostrils open separately or by a single crescentic valvular aperture, not at the extremity of the snout, but near the vertex.

Animals of the order *Cetacea* abound in all known seas, and some species are inhabitants of the larger rivers of South America and Asia. Their organization necessitates their life being passed entirely in the water, as on the land they are absolutely helpless; but they have to rise very frequently to the surface for the purpose of respiration. They are all predaceous, subsisting on living animal food of some kind. One genus alone (*Orca*) eats other warm-blooded animals, as seals and even members of its own order, both large and small. Some feed on fish, others on small floating crustacea, pteropods, and medusæ, while the staple food of many is constituted of the various species of Cephalopods, chiefly *Loligo* and other *Teuthidæ*, which must abound in some seas in vast numbers, as they form almost the entire support of some of the largest members of the order. With some exceptions the Cetacea generally are timid, inoffensive animals, active in their movements, sociable and gregarious in their habits.

Among the existing members of the order there are two very distinct types—the Toothed Whales, or *Odontoceti*, and the Baleene Whales, *Mystacoceti*, which present throughout their organization most markedly distinct structural characters, and have in the existing state of nature no transitional forms. The extinct *Zeuglodon*, so far as its characters are known, does not fall into either of these groups as now constituted, but is in some respects intermediate, and in others more resembles the generalized mammalian type.

The important and interesting problem of the origin of the Cetacea and their relations to other forms of life is at present involved in the greatest obscurity. They present no more signs of affinity with any of the lower classes of vertebrated animals than do many of the members of their own class. Indeed, in all that essentially distinguishes a mammal from one of the oviparous vertebrates, whether in the osseous, nervous, vascular, or reproductive systems, they are as truly mammalian as any, even the highest, members of the class. Any supposed signs of inferiority are, as we shall see, simply modifications in adaptation to their peculiar mode of life. Similar modifications are met with in another quite distinct group of mammalia, the *Sirenia*, and also, though in a less complete degree, in the aquatic Carnivora or seals. But these do not indicate any community of origin between these groups and the Cetacea. In fact, in the present state of our knowledge, the Cetacea are absolutely isolated, and little satisfactory reason has ever been given for deriving them from any one of the existing divisions of the class more than from any other. The question has indeed often been mooted whether they have been derived from land mammals at all, or whether they may not be the survivors of a primitive aquatic form which was the ancestor not only of the whales, but of all the other members of the class. The materials for, I will not say solving, but for throwing some light upon this problem, must be sought for in two regions—in the structure of the existing members of the order, and in its past history, as revealed by the discovery of fossil remains. In the present state of science it is chiefly on the former that we have to rely, and this, therefore, will first occupy our attention.

One of the most obvious external characteristics by which the mammalia are distinguished from other classes of vertebrates is the more or less complete clothing of the surface by the peculiar modification of epidermic tissue called hair. The Cetacea alone appear to be exceptions to this generalization. Their smooth, glistening exterior is, in the greater number of species, at all events, in adult life, absolutely bare, though the want of a hairy covering is compensated for functionally by peculiar modifications of the structure of the skin itself, the epidermis being greatly thickened, and a remarkable layer of dense fat closely incorporated with the tissue of the derm or true skin; modifications admirably adapted for retaining the warmth of the body, without any roughness of surface which might occasion friction and so interfere with perfect facility of gliding through the water. Close examination, however, shows that the mammalian character of hairiness is not entirely wanting in the Cetacea, although it is reduced to a most rudimentary and apparently functionless condition. Scattered, small, and generally delicate hairs have been detected in many species, both of the toothed and of the whalebone whales, but never in any situation but on the face, either in a row along the upper lip, around the blowholes, or on the chin, apparently representing the large, stiff "vibrissæ" or "whiskers" found in corresponding situations in many land mammals. In some cases these seem to persist throughout the life of the animal; more often they are only found in the young or even the fœtal state. In some species they have not been detected at any age.

Eschricht and Reinhardt counted in a new-born Greenland Right Whale (*Balæna mysticetus*) sixty-six hairs near the extremity of the upper jaw, and about fifty on each side of the lower lip, as well as a few around the blowholes, where they have also been seen in *Megaptera longimana* and *Balænoptera rostrata*. In a large Rorqual (*Balænoptera musculus*), quite adult and sixty-seven feet in length, stranded in Pevensey Bay in 1865, there were twenty-five white, straight, stiff hairs about half an inch in length, scattered somewhat irregularly on each side of the vertical ridge in which the skin terminated, extending over a space of nine inches in height and two and a half inches in breadth. The existence of these rudimentary hairs must have some significance beyond any possible utility they may be to the animal. Perhaps some better explanation may ultimately be found for them, but it must be admitted that they are extremely suggestive that we have here a case of heredity or conformation to a type of ancestor with a full hairy clothing, just on the point of yielding to complete adaptation to the conditions in which whales now dwell.

In the organs of the senses the Cetacea exhibit some remarkable adaptive modifications of structures essentially formed on the mammalian type, and not on that characteristic of the truly aquatic vertebrates, the fishes, which, if function were the only factor in the production of structure, they might be supposed to resemble.

The modifications of the organs of sight do not so much affect the eyeball as the accessory apparatus. To an animal whose surface is always bathed with fluid, the complex arrangement which mammals generally possess for keeping the surface of the transparent cornea moist and protected, the movable lids, the nictitating membrane, the lachrymal gland, and the arrangements for collecting and removing the superfluous tears when they have served their function cannot be needed, and hence we find these parts in a most rudimentary condition or altogether absent. In the same way the organ of hearing in its essential structure is entirely mammalian, having not only the sacculi and semicircular canals common to all but the lowest vertebrates, both the cochlea, and tympanic cavity with its ossicles and membrane, all, however, buried deep in the solid substance of the head; while the parts specially belonging to terrestrial mammals, those which collect the vibrations of the sound traveling through air, the pinna and the tube which conveys it to the sentient structures within, are entirely or practically wanting. Of the pinna or external ear there is no trace. The *meatus auditorius* is certainly there, reduced to a minute aperture in the skin like a hole made by the prick of a pin, and leading to a tube so fine and long that it cannot be a passage for either air or water, and therefore can have no appreciable function in connection with the organ of hearing, and must be classed with the other numerous rudimentary structures that whales exhibit.

The organ of smell, when it exists, offers still more remarkable evidence of the origin of the Cetacea. In fishes this organ is specially adapted for the perception of odorous substances permeating the water; the terminations of the olfactory nerves are spread over a cavity near the front part of the nose, to which the fluid in which the animals swim has free access, although it is quite unconnected with the respiratory passages. Mammals, on the other hand, smell substances with which the atmosphere they breathe is impregnated; their olfactory nerve is distributed over the more or less complex foldings of the lining of a cavity placed in the head, in immediate relation to the passages through which air is continually driven to and fro on its way to the lungs in respiration, and therefore in a most favorable position for receiving impressions from substances floating in that air. The whalebone whales have an organ of smell exactly on the mammalian type, but in a rudimentary condition. The perception of odorous substances diffused in the air, upon which many land mammals depend so much for obtaining their food, or for protection from danger, can be of little importance to them. In the more completely modified Odontocetes the olfactory apparatus, as well as that part of the brain specially related to the function of smell, is entirely wanting, but in both groups there is not the slightest trace of the specially aquatic olfactory organ of fishes. Its complete absence and the vestiges of the aerial organ of land mammals found in the Mystacocetes are the clearest possible indications of the origin of the Cetacea from air-breathing and air-smelling terrestrial mammalia. With their adaptation to an aquatic mode of existence, organs fitted only for smelling in air became useless, and so have dwindled or completely disappeared. Time and circumstances have not permitted the acquisition of anything analogous to the special aquatic smelling apparatus of fishes, the result being that whales are practically deprived of whatever advantage this sense may be to other animals.

It is characteristic of the greater number of mammalia to to have their jaws furnished with teeth having a definite structure and mode of development. In all the most typical forms these teeth are limited in number, not exceeding eleven on each side of each jaw, or forty-four in all, and are differentiated in shape in different parts of the series, being more simple in front, broader and more complex behind. Such a dentition is described as "heterodont." In most cases also there are two distinct sets of teeth during the lifetime of the animal, constituting a condition technically called "diphyodont."

All the Cetacea present some traces of teeth, which in structure and mode of development resemble those of mammals, and not those of the lower vertebrated classes, but they are always found in a more or less imperfect state. In the first place, at all events in existing species, they are never truly heterodont, all the teeth of the series resembling each other more or less, or belonging to the condition called "homodont," and not obeying the usual numerical rule, often falling short of, but in many cases greatly exceeding it. The most typical Odontocetes, or toothed whales, have a large number of similar, simple, conical, recurved, pointed teeth, alike on both sides, and in the upper and under jaws, admirably adapted for catching slippery, living prey, such as fish, which are swallowed whole without mastication. In one genus (*Pontoporia*) there may be as many as sixty of such teeth on each side of each jaw, making 240 in all. The more usual number is from twenty to thirty. These teeth are never changed, being "monophyodont," and they are, moreover, less firmly implanted in the jaws than in land mammals, having never more than one root, which is set in an alveolar socket, which is generally wide and loosely fitting, though perfectly sufficient for the simple purpose which the teeth have to serve.

Most singular modifications of this condition of dentition are met with in different genera of toothed whales, chiefly the result of suppression, sometimes of suppression of the greater number, combined with excessive development of a single pair. In one large group, the Ziphioids, although minute rudimentary teeth are occasionally found in young individuals, and sometimes throughout life, in both jaws, in the adults, the upper teeth are usually entirely absent, and those of the lower jaw reduced to two, which may be very large, and projecting like tusks from the mouth, as in *Mesoplodon*, or minute and entirely concealed beneath the gums, as in *Hyperoodon*—an animal which is for all practical purposes toothless, yet in which a pair of perfectly formed though buried teeth remain throughout life, wonderful examples of the persistence of rudimentary and to all appearance absolutely useless organs. Among the *Delphinidæ* similar cases are met with. In the genus *Grampus* the teeth are entirely absent in the upper, and few and early deciduous in the lower jaw. But the Narwhal exceeds all other Cetaceans, perhaps all other vertebrated animals, in the specialization of its dentition. Besides some irregular rudimentary teeth found in the young state, the entire dentition is reduced to a single pair, which lie horizontally in the upper jaw, and both of which in the female remain permanently concealed within the bone, so that this sex is practically toothless, while in the male the right tooth usually remains similarly concealed and abortive, and the left is immensely developed, attaining a length equal to more than half that of the entire animal, projecting horizontally from the head in the form of a cylindrical or slightly tapering pointed tusk, with the surface marked by spiral grooves or ridges.

The meaning and utility of some of these strange modifications it is impossible, in the imperfect state of our knowledge of the habits of the Cetacea, to explain; but the fact that in almost every case a more full number of rudimentary teeth is present in early stages of existence, which either disappear, or remain as concealed and functionless organs, points to the present condition in the aberrant and specialized forms as being one derived from the more generalized type, in which the teeth were numerous and equal.

The Mystacocetes, or Whalebone Whales, are distinguished by entire absence of teeth, at all events after birth. But it is a remarkable fact, first demonstrated by Geoffrey St. Hilaire, and since amply confirmed by Cuvier, Eschricht, Julin, and others, that in the fœtal state they have numerous minute calcified teeth lying in the dental groove of both upper and lower jaws. These attain their fullest development about the middle of fœtal life, after which period they are absorbed, no trace of them remaining at the time of birth. Their structure and mode of development has been shown to be exactly that characteristic of ordinary mammalian teeth, and it has also been observed that those at the posterior part of the series are larger, and have a bilobed form of crown, while those in front are simple and conical, a fact of considerable interest in connection with speculations as to the history of the group.

It is not until after the disappearance of these teeth that the baleen, or whalebone, makes its appearance. This remarkable structure, though, as will be presently shown, only a modification of a part existing in all mammals, is, in its specially developed condition as baleen, peculiar to one group of whales. It is therefore perfectly in accord with what might have been expected that it is comparatively late in making its appearance. Characters that are common to a large number of species appear early, those that are special to a few at a late period; alike both in the history of the race and of the individual.

Baleen consists of a series of flattened, horny plates, several hundred in number, on each side of the palate, separated by a bare interval along the middle line. They are placed transversely to the long axis of the palate, with very short spaces between them. Each plate or blade is somewhat triangular in form, with the base attached to the palate, and the apex hanging downward. The outer edge of the blade is hard and smooth, but the inner edge and

* Lecture delivered at the Royal Institution on the evening of Friday, May 25, 1883, by Prof. Flower, LL.D., F.R.S., F.Z.S., etc.

apex fray out into long, bristly fibers, so that the roof of the whale's mouth looks as if covered with hair, as described by Aristotle. The blades are longer near the middle of the series, and gradually diminish near the front and back of the mouth. The horny plates grow from a dense, fibrous, and highly vascular matrix, which covers the palatal surface of the maxillæ, and which sends out lamellar processes, one of which penetrates the base of each blade. Moreover, the free edge of these processes is covered with very long, vascular, thread-like papillæ, one of which forms the central axis of each of the hair-like epidermic fibers of which the blade is mainly composed. A transverse section of fresh whalebone shows that it is made up of numbers of these soft vascular papillæ, circular in outline, each surrounded by concentrically arranged epidermic cells, the whole bound together by other epidermic cells, which constitute the smooth cortical (so-called "enamel") surface of the blade, and which, disintegrating at the free edge, allows the individual fibers to become loose and to assume the hair-like appearance spoken of before. These fibers differ from hairs in not being formed in depressed follicles in the enderon, but rather resemble those of which the horn of the rhinoceros is composed. The blades are supported and bound together for a certain distance from their base by a mass of less hardened epithelium, secreted by the surface of the palatal membrane or matrix of the whalebone in the intervals of the lamellar processes. This is the "intermediate substance" of Hunter, the "gum" of the whalers.

The function of the whalebone is to strain the water from the small marine molluska, crustaceans, or fish upon which the whales subsist. In feeding they fill the immense mouth with water containing shoals of these small creatures, and then, on their closing the jaws and raising the tongue, so as to diminish the cavity of the month, the water streams out through the narrow intervals between the hairy fringe of the whalebone blades, and escapes through the lips, leaving the living prey to be swallowed. Almost all the other structures to which I am specially directing your attention are, as I have mentioned, in a more or less rudimentary state in the Cetacea; the baleen, on the other hand, is an example of an exactly contrary condition, but an equally instructive one, as illustrating the mode in which nature works in producing the infinite variety we see in animal structures. Although appearing at first sight an entirely distinct and special formation, it evidently consists of nothing more than the highly modified papillæ of the lining membrane of the mouth, with an excessive and cornified epithelial development.

The bony palate of all mammals is covered with a closely adhering layer of fibro-vascular tissue, the surface of which is protected by a coating of non-vascular epithelium, the former exactly corresponding to the derm or true skin, and the latter to the epiderm of the external surface of the body. Sometimes this membrane is perfectly smooth, but it is more often raised into ridges, which run in a direction transverse to the axis of the head, and are curved with the concavity backward. The ridges moreover do not extend across the middle line, being interrupted by a median depression or *raphé*. Indications of these ridges are clearly seen in the human palate, but they attain their greatest development in the Ungulata. In oxen, and especially in the giraffe, they form distinct laminæ, and their free edges develop a row of papillæ, giving them a pectinated appearance. Their epithelium is thick, hard, and white, though not horny. Although the interval between the structure of the ridges in the giraffe's palate and the most rudimentary form of baleen at present known is great, there is no difficulty in seeing that the latter is essentially a modification of the former, just as the hoof of the horse, with its basis of highly developed vascular laminæ and papillæ, and the resultant complex of the arrangement of the epidermic cells, is a modification of the simple nail or claw of other mammals, or as the horn of the rhinoceros is only a modification of the ordinary derm and epiderm covering the animal's body, differentiated by a local exuberance of growth.

Though the early stages by which whalebone has been modified from more simple palate structures are entirely lost to our sight, probably for ever, the conditions in which it now exists in different species of whales show very marked varieties of progress, from a simple comparatively rudimental and imperfect condition to what is perhaps the most wonderful example of mechanical adaptation to purpose known in any organic structure. These variations are worth dwelling upon for a few minutes, as they illustrate in an excellent manner the gradual modifications that may take place in an organ, evidently in adaptation to particular requirements, the causation of which can be perfectly explained upon Darwin's principle of natural selection.

In the Rorquals or fin-whales (genus *Balænoptera*), found in almost all seas, and so well known off our own coasts, the largest blades in an animal of 70 feet in length do not exceed 2 feet in length, including their hairy terminations; they are in most species of a pale horn color, and their structure is coarse and inelastic, separating into thick, stiff fibers, so that they are of no value for the ordinary purposes to which whalebone is applied in the arts. These animals feed on fish of considerable size, from herrings up to cod, and for foraging among shoals of these creatures the construction of their mouth and the structure of their baleen is evidently sufficient. This is the type of the earliest known extinct forms of whales, and it has continued to exist, with several slight modifications, to this day, because it has fulfilled one purpose in the economy of nature. Other purposes for which it was not sufficient have been supplied by gradual changes taking place, some of the stages of which are seen in the intermediate conditions still exhibited in the Megaptera, and the Atlantic and Southern Right Whales. Before describing the extreme modifications in the direction of complexity, I may mention, to show the range at present presented in the development of baleen, that there has lately been discovered in the North Pacific a species called by the whalers the Californian Gray Whale (*Rachianectes glaucus*), which shows the opposite extreme of simplicity. The animal is from 30 to 40 feet in length; the baleen blades are only 182 on each side (according to Scammon) and far apart, very short (the longest being from 14 to 16 inches in length), light brown or nearly white in color, and still more coarse in grain and inelastic than that of the Rorquals. The food of these whales is not yet known with certainty. They have been seen apparently seeking for it along soft bottoms of the sea, and fuci and mussels have been found in their stomachs.

In the Greenland Right Whale of the circumpolar seas, the Bow-head of the American whalers (*Balæna mysticetus*), all the peculiarities which distinguish the head and mouth of the whales from other mammals have attained their greatest development. The head is of enormous size, exceeding one-third of the whole length of the creature. The cavity of the mouth is actually larger than that of the body, thorax, and abdomen together. The upper jaw is very narrow, but greatly arched from before backward, to increase the height of the cavity and allow for the great length of the baleen, the enormous rami of the mandibles are widely separated posteriorly, and have a still further outward sweep before they meet at the symphysis in front, giving the floor of the mouth the shape of an immense spoon. The baleen blades attain the number of 350 or more on each side, and those in the middle of the series have a length of ten or even twelve feet. They are black in color, fine, and highly elastic in texture, and fray out at the inner edge and ends into long, delicate, soft, almost silky, but very tough hairs.

How these immensely long blades depending vertically from the palate were packed into a mouth the height of which was scarcely more than half their length was a mystery not solved until a few years ago. Captain David Gray, of Peterhead, at my request, first gave us a clear idea of the arrangement of the baleen in the Greenland whale, and showed that the purpose of its wonderful elasticity was not primarily at least the benefit of the corset and umbrella makers, but that it was essential for the correct performance of its functions. It may here be mentioned that the modification of the mouth structure of the Right Whale is entirely in relation to its food. It is by this apparatus that it is enabled to avail itself of the minute but highly nutritious crustaceans and pteropods which swarm in immense shoals in the seas it frequents. The large mouth enables it to take in at one time a sufficient quantity of water filled with these small organisms, and the length and delicate structure of the baleen provides an efficient strainer or hair sieve by which the water can be drained off. If the baleen were, as in the Rorquals, short and rigid, and only of the length of the aperture between the upper and lower jaws when the mouth was shut, when the jaws were separated a space would be left beneath it through which the water and the minute particles of food would escape together. But instead of this, the long, slender, brush-like ends of the whalebone blades when the mouth is closed, fold back, the front ones passing below the hinder ones in a channel lying between the tongue and the bone of the lower jaw. When the mouth is opened their elasticity causes them to straighten out like a bow that is unbent, so that at whatever distance the jaws are separated, the strainer remains in perfect action, filling the whole of the interval. The mechanical perfection of the arrangement is completed by the great development of the lower lip, which rises stiffly above the jaw-bone, and prevents the long, slender, flexible ends of the baleen being carried outward by the rush of water from the mouth, when its cavity is being diminished by the closure of the jaws and raising of the tongue. The interest and admiration excited by the contemplation of such a beautifully adjusted piece of mechanism is certainly heightened by the knowledge that it has been brought about by the gradual adaptation and perfection of structures common to the whole class of animals to which the whale belongs.

Few points of the structure of whales offer so great a departure from the ordinary mammalian type as the limbs. The fore-limbs are reduced to the condition of simple paddles or oars, variously shaped, but always flattened and more or less oval in outline. They are freely movable at the shoulder-joint, where the humerus or upper-arm bone articulates with the shoulder-blade in the usual manner, but beyond this point, except a slight flexibility and elasticity, there is no motion between the different segments. The bones are all there, corresponding in number and general relations with those of the human or any other mammalian arm, but they are flattened out, and their contiguous ends, instead of presenting hinge-like joints, come in contact by flat surfaces, united together by strong ligamentous bands, and all wrapped up in an undivided covering of skin, which allows externally of no sign of the separate and many-jointed fingers seen in the skeleton.

Up to the year 1865 it was generally thought that there was nothing to be found between this bony framework and the covering skin, with its inner layer of blubber, except dense fibrous tissue, with blood-vessels and nerves sufficient to maintain its vitality. Dissecting a large Rorqual, 67 feet in length, upon the beach of Pevensey Bay in that year, I was surprised to find lying upon the bones of the fore-arm well-developed muscles, the red fibers of which reached nearly to the lower end of these bones, ending in strong tendons, passing to, and radiating out on, the palmar surface of the hand. Circumstances then prevented me following out the details of their arrangement and distribution, but not long afterward Prof. Struthers, of Aberdeen, had an opportunity of carefully dissecting the fore-limb of another whale of the same species, and he has recorded and figured his observations in the *Journal of Anatomy*, for November, 1871.

He found on the internal or palmar aspect of the limb three distinct muscles corresponding in attachments to the flexor carpi ulnaris, the flexor profundus digitorum, and the flexor longus pollicis of man, and on the opposite side but one, the extensor communis digitorum.* Large as these muscles actually are, yet, compared with the size of the animal, they cannot but be regarded as rudimentary; and being attached to bones without regular joints and firmly held together by unyielding tissues, their functions must be reduced almost to nothing. But rudimentary as the muscles of the Fin-whales are, lower stages of degradation of the same structures are found in other members of the group. In some they are indeed present in form, but their muscular structure is gone and they are reduced in most of the toothed whales to mere fibrous bands, scarcely distinguishable from the surrounding tissue, which connects the inner surface of the skin with the bone. It is impossible to contemplate these structures without having the conviction forced home that here are the remains of parts once of use to their possessor, now, owing to the complete change of purpose and mode of action of the limb, reduced to a condition of atrophy verging on complete disappearance.

The changes that have taken place in the hind-limbs are even more remarkable. In all known Cetacea (unless *Platanista* be really an exception) a pair of slender bones are found suspended a short distance below the vertebral column, but not attached to it, about the part where the body and the tail join. In museum skeletons these bones are often not seen, as, unless special care has been taken in the preparation, they are apt to get lost. They are, however, of much importance and interest, as their relations to surrounding parts show that they are the rudimentary representatives of the pelvic or hip bones, which in other mammals play such an important part in connecting the hind limbs with the rest of the skeleton. The pelvic arch is thus almost universally present, but of the limb proper there is, as far as is yet known, not a vestige in any of the large group of toothed whales, not even in the great Cachalot or Sperm Whale, although it should be mentioned that it has never been looked for in that animal with any sort of care.

With regard to the Whalebone Whales, at least to some of the species, the case is different. In these animals there are found, attached to the outer and lower side of the pelvic bone, other elements, bony or only cartilaginous as the case may be, clearly representing rudiments of the first and in some cases the second segment of the limb, the thigh, or femur, and the leg, or tibia. In the small *Balænoptera rostrata* a few thin fragments of cartilage, embedded in fibrous tissue attached to the side of the pelvic bone, constitute the most rudimentary possible condition of a hind limb, and could not be recognized as such but for their analogy with other allied cases. In the large Rorqual, *Balænoptera musculus*, 67 feet long, previously spoken of, I was fortunate enough in 1865 to find attached by fibrous tissue to the side of the pelvic bone (which was sixteen inches in length) a distinct femur, consisting of a nodule of cartilage of a slightly compressed, irregularly oval form, and not quite one inch and a half in length.

Other specimens of the same animal dissected by Van Beneden and Prof. Struthers have shown the same; in one case, partial ossification had taken place. In the genus *Megaptera* a similar femur has been described by Eschricht, and the observations of Reinhardt have shown that the Greenland Right Whale (*Balæna mysticetus*) has not only a representative of the femur developed far more completely than in the Rorqual, being from six to eight inches in length and completely ossified, but also a second smaller and more irregularly formed bone, representing the tibia. Our knowledge of these parts in this species has recently been greatly extended by the researches of Dr. Struthers, of Aberdeen, who has published in the *Journal of Anatomy*, for 1881, a most careful and detailed account of the dissection of several specimens, showing the amount of variation to which these bones (as with most rudimentary structures) are liable in different individuals, and describing for the first time their distinct articulation one with the other by synovial joints and capsular ligaments, and also the most remarkable and unlooked-for presence of muscles passing from one bone to the other, representing the adductors and flexors of mammals with completely developed limbs, but so situated that it is almost impossible to conceive that they can be of any use; the whole limb, such as it is, being buried deep below the surface, where any movement, except of the most limited kind, must be impossible. Indeed, that the movement is very limited and of no particular importance to the animal was shown by the fact that in two out of eleven whales dissected the hip-joint was firmly anchylosed (or fixed by bony union), though without any trace of disease. In the words of Dr. Struthers, "Nothing can be imagined more useless to the animal than rudiments of hind-legs entirely buried beneath the skin of a whale, so that one is inclined to suspect that these structures must admit of some other interpretation. Yet, approaching the inquiry with the most skeptical determination, one cannot help being convinced, as the dissection goes on, that these rudiments really are femur and tibia. The functional point of view fails to account for their presence. Altogether they present for contemplation a most interesting instance of those significant parts, rudimentary structures."

We have here a case in which it is not difficult to answer the question before alluded to, often asked with regard to rudimentary parts, Are they disappearing or are they incipient organs? We can have no hesitation in saying that they are the former. All we know of the origin of limbs shows that they commence as outgrowths upon the surface of the body, and that the first formed portions are the most distal segments. The limb, as proved by its permanent state in the lowest Vertebrates, and by its embryological condition in higher forms, is at first a mere projection or outward fold of the skin, which, in the course of development, as it becomes of use in moving or supporting the animal, acquires the internal framework which strengthens it and perfects its functions. It would be impossible, on any theory of causation yet known, to conceive of a limb gradually developed from within outward. On the other hand, its disappearance would naturally take place in the opposite direction; projecting parts which had become useless, being in the way, would, like all the other prominences on the surface of the whales, hair, ears, etc., be removed, while the most internal, offering far less interference with successfully carrying on the purposes of life, would be the last to disappear, lingering, as in the case of the Greenland Whale, long enough to reveal their wonderful history to the anatomist who has been fortunate enough to possess the skill and the insight to interpret it.

Time will not allow of more illustrations drawn from the structure of existing Cetacea; we turn next to what the researches of palæontology teach of the past history of the order. Unfortunately, this does not at present amount to very much. As is the case with nearly all other orders of mammals, we know nothing of their condition, if they existed, in the Mesozoic age. Even in the Cretaceous seas, the deposits at the bottom of which are so well adapted to preserve the remains of the creatures which swam in them, not a fragment of any whale or whale-like animal has been found. The earliest Cetaceans of whose organization we have any good evidence are the Zeuglodons of the Eocene formations of North America. These were creatures whose structure, as far as we know it, was intermediate between that of the existing suborders of whales, having the elongated nasal bones and anterior position of the nostrils of the Mystacocetes, with the teeth of the Odontocetes, and with some characters more like those of the generalized mammalian type than of any of the existing forms. In fact, *Zeuglodon* is precisely what we might have expected *a priori* an ancestral form of whale to have been. The remarkable smallness of its cerebral cavity, compared with the jaws and the rest of the skull, so different from that of modern Cetaceans, is exactly paralleled in the primitive types of other groups of mammals. The teeth are markedly differentiated in different parts of the series. In the anterior part of both jaws they are simple, conical, or slightly compressed and sharp pointed. The first three of the upper jaw are distinctly implanted in the premaxillary bone, and so may be reckoned as incisors. The tooth which succeeds, or the canine, is also simple and conical, but it does not greatly exceed the others in size. This is followed by five teeth with two distinct roots and compressed pointed crowns, with denticulated cutting edges. It has been thought that there was evidence of a vertical succession of the molar teeth, as in diphyodont mammals, but the proof of this is not quite satisfactory. Unfortunately, the structure of the limbs is most imperfectly known, A mutilated humerus has given rise to many conjectures; to some anatomists it appears to indicate freedom of motion at the elbow-joint, while to others its characters seem to be those of the ordinary Ceta-

* The muscles of the fore-arm of an allied species, *Balænoptera rostrata*, were described by Macalister in 1868, and Perrin in 1870.

cea. Of the structure of the pelvis and hind-limb we are at present in ignorance.

From the middle Miocene period fossil Cetacea are abundant and distinctly divided into the two groups now existing. The Mystacocetes, or Whalebone Whales, of the Miocene seas were, as far as we know now, only *Balænopteræ*, some of which (as the genus *Cetotherium*) were, in the elongated flattened form of the nasal bones, the greater distance between the occipital and frontal bone at the top of the head, and the greater length of the crevical vertebræ, more generalized than any now existing. In the shape of the mandible also, Van Beneden, to whose researches we are chiefly indebted for a knowledge of these forms, discerns some approximation to the Odontocetes. Right Whales (*Balæna*) have not been found earlier than the Pliocene period, and it is interesting to note that instead of the individuals diminishing in bulk as we approach the times we live in, as with many other groups of animals, the contrary has been the case, no known extinct species of whales equaling in size those that are now to be met with in the ocean. The size of whales, as of all other things whose most striking attribute is magnitude, has been greatly exaggerated: but when reduced to the limits of sober fact, the Greenland Right Whale of 50 feet long, the Sperm Whale of 60, and the Great Northern Rorqual (*Balænoptera sibbaldii*) of 80 exceed all other organic structures known, past or present. Instead of living in an age of degeneracy of physical growth we are in an age of giants, but it may be at the end of that age. For countless ages impulses from within and the forces of circumstances from without have been gradually shaping the whales into their present wonderful form and gigantic size, but the very perfection of their structure and their magnitude combined, the rich supply of oil protecting their internal parts from cold, the beautiful apparatus of whalebone by which their nutrition is provided for, have been fatal gifts, which under the sudden revolution produced on the surface of the globe by the development of the wants and arts of civilized man, cannot but lead in a few years to their extinction.

It does not need much foresight to divine the future history of whales, but let us return to the question with which we started—What was their probable origin?

In the first place, the evidence is absolutely conclusive that they were not originally aquatic in habit, but are derived from terrestrial mammals of fairly high organization, belonging to the placental division of the class—animals in which a hairy covering was developed, and with sense organs, especially that of smell, adapted for living on land; animals, moreover, with four completely developed pairs of limbs on the type of the higher vertebrata, and not of that of fishes. Although their teeth are now of the simple homodont and diphyodont type, there is much evidence to show that this has taken place by the process of degradation from a more perfect type, even the fœtal teeth of Whalebone Whales showing signs of differentiation into molars and incisors, and many extinct forms, not only the Zeuglodons, but also true dolphins, as the Squalodons, having a distinct heterodont dentition, the loss of which, though technically called a "degradation," has been a change in conformity to the habits and needs of the individuals. So much may be considered very nearly if not quite within the range of demonstrated facts, but it is in determining the particular group of mammals from which the Cetacea arose that greater difficulties are met with.

One of the methods by which a land mammal may have been changed into an aquatic one is clearly shown in the stages which still survive among the Carnivora. The seals are obviously modifications of the land Carnivora, the Otaria, or Sea-lions and Sea-bears, being curiously intermediate. Many naturalists have been tempted to think that the whales represent a still further stage of the same kind of modification. So firmly has this idea taken root, that in most popular works on zoology in which an attempt is made to trace the pedigree of existing mammals, the Cetacea are definitely placed as offshots of the Pinnipedia, which in their turn are derived from the Carnivora. But there is to my mind a fatal objection to this view. The seal of course has much in common with the whale, inasmuch as it is a mammal adapted for an aquatic life, but it has been converted to its general fishlike form by the peculiar development of its hind-limbs into instruments of propulsion through the water; for though the thighs and legs are small, the feet are large and are the special organs of locomotion in the water, the tail being quite rudimentary. The two feet applied together form an organ very like the tail of a fish or whale, and functionally representing it, but only functionally, for the time has I trust quite gone by when the Cetacea were defined as animals with the "hinder limbs united, forming a forked horizontal tail." In the whales, as we have seen, the hind-limbs are aborted and the tale developed into a powerful swimming organ. Now it is very difficult to suppose that when the hind-limbs had once become so well adapted to a function so essential to the welfare of the animal as that of swimming, they could ever have become reduced and their action transferred to the tail; the animal must have been in a too helpless condition to maintain its existence during the transference, if it took place, as we must suppose, gradually. It is far more reasonable to suppose that whales were derived from animals with large tails, which were used in swimming, eventually with such effect that the hind-limbs became no longer necessary, and so gradually disappeared. The powerful tail, with lateral cutaneous flanges, of an American species of Otter (*Pteronura sandbachii*) or the still more familiar tail of the beaver, may give some idea of this member in the primitive *Cetacea*. I think that this consideration disposes of the principal argument that the whales are related to the seals, as most of the other resemblances, such as those in the characters of their teeth, are evidently analogous resemblances related to similarity of habit.

As pointed out long ago by Hunter, there are numerous points in the structure of the visceral organs of the Cetacea far more resembling those of the Ungulata than the Carnivora. These are the complex stomach, simple liver, respiratory organs, and especially the reproductive organs and structures relating to the development of the young. Even the skull of Zeuglodon, which has been cited as presenting a great resemblance to that of a seal, has quite as much likeness to one of the primitive pig-like Ungulates, except in the purely adaptive character of the form of the teeth.

Though there is, perhaps, generally more error than truth in popular ideas on natural history, I cannot help thinking that some insight has been shown in the common names attached to one of the most familar of Cetaceans by those whose opportunities of knowing its nature have been greatest—"Sea-hog," "Sea-pig" or "Herring-hog" of our fishermen, *Meerschwein* of the Germans, corrupted into the French "Marsouin," and also "Porcpoisson," shortened into "Porpoise."

A difficulty that might be suggested in the derivation of the Cetacea from the Ungulata, arising from the latter being at the present day mainly vegetable feeders, is not great, as the primitive Ungulates were probably omnivorous, as their least modified descendants, the pigs, are still, and the aquatic branch might easily have gradually become more and more piscivorous, as we know from the structure of their bones and teeth, the purely terrestrial members have become by degrees more exclusively graminivorous.

One other consideration may remove some of the difficulties that may arise in contemplating the transition of land mammals into whales. The Gangetic Dolphin (*Platanista*) and the somewhat related *Inia* of South America, which retain several rather generalized mammalian characters, and are related to some of the earliest known European Miocene forms, are both to the present day exclusively fluvintile, being found in the rivers they inhabit almost up to their very sources, more than a thousand miles from the sea. May this not point to the freshwater origin of the whole group, and thus account for their otherwise inexplicable absence from the Cretaceous seas?

We may conclude by picturing to ourselves some primitive generalized, marsh-haunting animals with scanty covering of hair like the modern hippopotamus, but with broad, swimming tails and short limbs, omnivorous in their mode of feeding, probably combining water plants with mussels, worms, and fresh water crustaceans, gradually becoming more and more adapted to fill the void place ready for them on the aquatic side of the borderland on which they dwelt, and so by degrees being modified into dolphin-creatures inhabiting lakes and rivers, and ultimately finding their way into the ocean. Here the disappearance of the huge Enaliosaurians, the *Ichthyosauri* and *Plesiosauri*, which formerly played the part the Cetacea do now, had left them ample scope. Favored by various conditions of temperature and climate, wealth of food supply, almost complete immunity from deadly enemies, and illimitable expanses in which to roam, they have undergone the various modifications to which the Cetacean type has now arrived, and gradually attained that colossal magnitude which we have seen was not always an attribute of the animals of this group.

Please to recollect, however, that this is a mere speculation, which may or may not be confirmed by subsequent palæontological discovery. Such speculations are, I trust, not without their use and interest, especially when it is distinctly understood that they are offered only as speculations, and not as demonstrated facts.

THE SHEEP GRUB.

DURING the hot days of mid-summer, sheep often huddle together with their noses upon the ground, or in some other constrained position. This is done partly at least, to secure them from the attacks of the pestering gad-fly (*Œstrus ovis*), which is the parent of the annoying grub-in-the-head. This insect is closely related to the bot-fly, that deposits its eggs upon the neck, shoulders, and forelegs of horses, from which they are removed by the teeth of the animal to allay the itching and are taken into the stomach, and developed into troublesome bots. The female sheep gad-fly aims to deposit her eggs in the nostrils of the sheep, and the animals, apparently aware of the effects to follow, try to prevent it. If the eggs are laid, they soon hatch, and the yong grubs ascend the nostrils, greatly to the distress of the affected sheep. The "worms" attach themselves to the sinuses of the nose, by means of hooks like those of the horse bot, and live upon the mucous secretions of the irritated surface to which they cling. When fully grown, the grubs work their way down through the narrow openings by which they entered when first hatched and again cause the sheep much pain. The grubs fall to the ground, and burrowing for a few inches, become chrysalids, which developed into the perfect flies in about two months. The grubs pass from the sheep in early summer, and the flies come out of the ground from July to September. A daub of tar upon the nose is the best preventive, and should be frequently applied during the summer months. This may be done by sprinkling some meal or salt over the tar in a trough when the sheep will apply it themselves as they eat the meal. Some farmers plow furrows in the pasture, to furnish the sheep a good place to bury their nose. The sheep grub is not fatal, but very disagreeable, and doubtless has a bad effect on the general health of infected sheep. If any one desires to study the grubs, he may find them in many of the heads of sheep killed at the shambles.—*American Agriculturist*.

THE ELEVATED CORAL REEFS OF CUBA.

By W. O. CROSBY, Proc. Boston Soc. Nat. Hist.

MR. CROSBY describes, in this paper, the elevated coral reefs of Cuba, and draws from them the apparently well sustained conclusion that they indicate a slow subsidence during their formation, and hence, further, that Darwin's theory of the origin of coral islands is the true theory. The *lowest* reef-terrace, of the northern side of the island, has a height of thirty feet, and varies in width from a few rods to a mile; it was once, plainly, the fringing reef of the shore. The *second* reef-terrace rises abruptly from the level of the lower to a height of 200 to 250 feet, and bears evidence of having been of like origin with the lower. The altitude of the *third* reef is about 500 feet; and the *fourth* has a height east of Baracoa, near the Yumuri River, "of probably not less than 800 feet." These old reef-terraces extend, "with slight interruptions, around the entire coast of Cuba; and in the western part of the island, where the erosion is less rapid than farther east, they are the predominant formation, and they are well preserved on the summits of the highest hills. Mr. Alexander Agassiz states that the hills about Havana and Matanzas, which reach a height of over 200 feet, are entirely composed of reef-limestone."

In the precipitous mountain call El Yunque (the Anvil), five miles west of Baracoa, reef limestone, 1,000 feet thick, constitutes the upper half of the mountain, the lower part, on which the reef rests, consisting of eruptive rocks and slates; and originally the upper limit of this modern limestone formation must have been 2,000 feet above the sea-level. Mr. Sawkins gives 2,000 feet as the maximum thickness of the Jamaica elevated coral reefs above the sea.

Evidence that the reefs were not formed during a progressive rising of the land is drawn from the thickness of the reefs. Mr. Crosby observes that the reefs reaching to a height of 500 and 1,000 feet—if not also that to a height of 2,000 feet—show, by the remains within them, that they were not made chiefly of reef-building corals, and hence, that they were not begun in deep water, as is assumed in the theory of Mr. Agassiz, but that they were made in shallow water during a progressive subsidence. Mr. Crosby concludes as follows:

"We have then apparently no recourse but to accept Darwin's theory as an adequate explanation of the elevated reefs of the Greater Antilles; and, therefore, to admit that upheaval of this portion of the earth's crust has been interrupted by periods of profound subsidence, during which the reefs were formed. The subsidence of 2,000 feet, of which El Yunque is a monument, must have reduced the Greater Antilles to a few lines of small but high and ragged islands; and, as Mr. Bland has shown, this fully accounts for the absence in these immense tracts of all large animals, although they were abundant here in Pliocene and earlier times."

The writer adds here the following objections to the theory of the formation of coral atolls in deep waters out of the calcareous secretions of deep-water life: (1) It is very improbable that submarine eruptions ever make the large and well defined craters, like those of subaerial action, which are appealed to in order to explain the lagoon feature of atolls; (2) many coral atolls are twenty miles or more in diameter, which is vastly larger than the largest of craters; (3) the atolls are never circular, and the larger have the irregularities of outline or diversities of form characterizing other large islands of the ocean; (4) in the actual reefs and islands of the Fiji group (see the map of the Islands in the writer's Coral and Coral Islands), all the conditions, from the first stage to that of the almost completed atoll, are well illustrated, one island having only a single peak of rock within the lagoon, not $\frac{1}{100}$ of the whole area, which a little more of subsidence would put beneath the waters and leave the lagoon wholly free.—*American Journal of Science*.

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